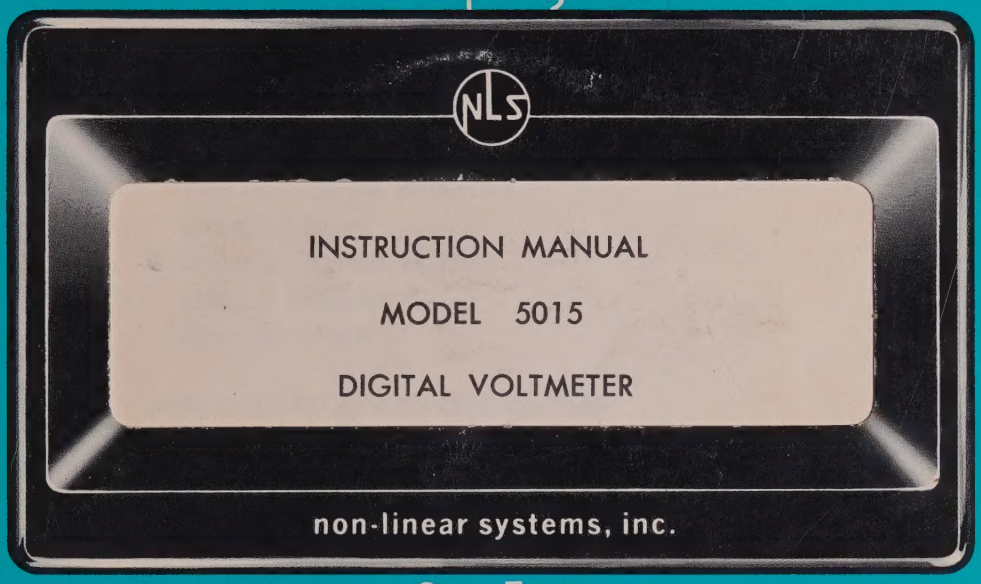
RETURN TO:
DAC PRELSUK
GR 5



non linear
systems, inc.

DEL MAR, CALIFORNIA

INSTRUCTION MANUAL

MODEL 5015

DIGITAL VOLTMETER

D & E Pressure Grp.

This manual is for instrument Serial No. 5015.396

Originator of the Digital Voltmeter

non-linear systems, inc.

DEL MAR , CALIFORNIA

Printed in the United States of America

Entire contents copyright, 1965. No part of this book may be reproduced without written permission from Non-Linear Systems, Inc., Del Mar, Calif.

TABLE OF CONTENTS

Chapter		Page
I	INTRODUCTION AND SPECIFICATIONS	1-1
	Accurate and Stable	1-1
	Easy to Service	1-1
	Common-Mode Rejection	1-1
	Floating Input	1-2
	Printed Circuit Boards	1-2
	Digital Readout	1-2
	Specifications	1-2
II	INSTALLATION AND OPERATION	2-1
	Unpacking	2-1
	Power Source	2-1
	Fusing	2-1
	Power Grounding	2-1
	Cables	2-4
	Controls	2-4
III	THEORY OF OPERATION	3-1
	Basic Theory	3-1
	Input Signal Filter	3-1
	Range Attenuator	3-2
	Range Attenuator Operation	3-5
	Error Comparator	3-5
	Error Comparator - Linear Pulse Amplifier Operation	3-10
	Range Logic	3-15
	Decade Assembly	3-17
	Relay Logic	3-19
	Relay Buffer	3-22
IV	Power Supply Assembly	3-23
	Print Operation	3-23
IV	CALIBRATION	4-1
	Equipment Required	4-1
	Initial Preparation	4-1
	Gain Adjustment	4-4
	Basic Accuracy Calibration	4-4

TABLE OF CONTENTS (CONT)

Chapter		Page
IV	CALIBRATION (Cont)	
	Range Calibration	4-4
	Final Accuracy Calibration	4-5
	Final Gain Check	4-5
V	MAINTENANCE	5-1
	Relay Handling	5-1
	Digital Readout Maintenance	5-3
	Lamp Bulb Replacement	5-3
	Readout Window Cleaning	5-5
VI	PARTS LIST	6-1
	APPENDIX	I
	Shipping Instructions	I
	Claim For Damage In Shipment	I

LIST OF ILLUSTRATIONS

Figure	Title	Page
2-1	Power Plug Pin Coding	2-1
2-2	Input Cable	2-2
2-3	Input Connections	2-2
2-4	Front Panel	2-3
2-5	Rear View	2-3
3-1	Model 5015 Digital Voltmeter Block Diagram	3-3
3-2	Range Logic Simplified Schematic Diagram	3-6
3-3	Attenuator Relay Contact Connectors	3-7
3-4	Error Comparator Simplified Schematic Diagram	3-8
3-5	Error Comparator Voltage Wave Form	3-8
3-6	Linear Pulse Amplifier Simplified Schematic Diagram	3-9
3-7	Two-Transistor Feedback Amplifier Simplified Schematic Diagram	3-12
3-8	Output Stage Schematic Diagram	3-14
3-9	Silicon Switch Controlled Circuit	3-14
3-10	Threshold Detector Schematic Diagram	3-16
3-11	Threshold Detector Timing Chart	3-16
3-12	Truth Table for Decade Counter	3-18

LIST OF ILLUSTRATIONS (Cont)

Figure	Title	Page
3-13	Wolf-Poggendorf Bridge Section	3-19
3-14	Relay Logic Simplified Schematic Diagram	3-19
3-15	Typical Flip-Flop Circuit Simplified Schematic Diagram	3-21
3-16	Relay Buffer Simplified Schematic Diagram	3-22
3-17	Power Supply Simplified Block Diagram	3-24
4-1	Location of Adjustment Points	4-2
4-2	Cable Connections	4-3
4-3	Cable Connections	4-3
5-1	Readout Asssembly	5-4
5-2	Lamp Bulb Contact Points	5-4
	DVM Assembly (Top View)	6-2
	DVM Assembly (Bottom View)	6-3
	Amplifier, Range and Polarity	6-4
	Decade Assembly	6-6
	Power Supply Assembly	6-7
	Logic Assembly	6-8

LIST OF TABLES

Table	Title	Page
5-1	Troubleshooting	5-2

LIST OF SCHEMATIC DIAGRAMS

50-7	Power Supply Assembly
50-61	Decade Assembly
50-67	DVL-1 Print Control Board
50-114	Decade Assembly
50-154	Main Board Assembly
50-177	Amplifier Assembly
50-192	Logic Assembly
50-202	DVL-1 Addition for 5 Digit Print-Out

CHAPTER I

INTRODUCTION AND SPECIFICATIONS

The NLS Model 5015 Digital Voltmeter is designed for users who require a highly accurate, easily-maintained instrument possessing a high order of reliability.

Although presented in greater detail elsewhere in this manual, the leading particulars of these instruments are here summarized to illustrate how NLS has met user demand, and to familiarize the reader with the instruments.

ACCURATE AND STABLE

For maximum accuracy and stability, the Model 5015 operates as an automated version of the laboratory potentiometer, the most accurate voltage measuring device. Using a relay-operated digital feedback voltage divider, energized by a 10-volt Zener reference voltage, this instrument creates a precision feedback voltage equal to the unknown input. The feedback and unknown input are continually compared by an error amplifier which, should a difference occur, issues commands to reposition the feedback voltage divider. Operation on the 100-volt and 1000-volt ranges is achieved by an automatically-operated attenuator which divides the unknown input by 10 or 100 respectively. Ultra-stable, carefully matched and aged Zener diodes provide the self-balancing digital potentiometer excitation voltage. A temperature-controlled oven is not required.

EASY TO SERVICE

Virtually all components are mounted on plug-in circuit boards for easiest access and replacement. It is thus possible to keep the model 5015 operative with a minimum of down time. Hours spent in troubleshooting activities are now replaced by minutes spent in module replacement. For example, logic and feedback voltage generator circuits, common to any one decade, (readout window) are mounted on a separate board and decades 1, 2, 3, and 4 are interchangeable; decade 5 will fit into any of the five positions, but the mating connector for decade 5 will not receive the decade 1, 2, 3, or 4 boards.

COMMON-MODE REJECTION

Rejection of common-mode signals, those caused by AC or DC currents flowing between signal source ground and instrument case ground, is a key feature of the Model 5015 Digital Voltmeter. Common-mode signal rejection is important in a wide range of applications - testing complex electrical and electronic systems, in automatic measuring systems, and measuring outputs from thermocouples, strain gauges and other transducers where common-mode signals may be many times greater than the measured DC voltage.

In the Model 5015, 60 CPS common-mode signals of 106 DB (minimum) will have no effect upon measurement accuracy even with up to 1,000 ohms source unbalance in either side of the input line. This feature is attained because the measuring circuits are isolated from the outer case by a metal guard shield that breaks the common-mode current loop and because the power supply is isolated from the power line.

FLOATING INPUT

Because input signal leads are not connected to the 5015 instrument's outer case, signal-to-case potentials up to 500 volts are tolerable. Floating input adds to the unit's versatility by permitting it to measure voltage sources which could not be accurately measured by a non-isolated meter.

PRINTED CIRCUIT BOARDS

Epoxy fiberglass, rather than phenolic printed-circuit boards, are used throughout the instrument to minimize circuit breakage caused by expansion and contraction. For additional mechanical and electrical stability, the Printact relays used in the instruments are mounted on individual circuit boards. These small relay boards are not subject to many of the mechanical stresses which act upon the larger component boards, and therefore, the relay contact surfaces are more likely to stay in alignment. Electrical contact quality is assured, not only by the use of precious metal contact surfaces on both the printed circuit board and the relay contacts. The relays themselves are very conservatively rated by their manufacturer at ten years use at one reading each twenty seconds per eight-hour day.

DIGITAL READOUT

The readout is the time-proven NLS lucite-panel, edge-lighted type in which each decade is housed in a separate module. The lamps used in this readout have been expressly designed for use in NLS readouts to combine high brilliance with long life. Since the lamps operate at transistor voltages, there is no electrical shock hazard to the user.

The NLS Sales Representatives or Engineering Department will be pleased to assist you with specific application problems and, of course, will gladly welcome your comments and suggestions. A contact with the nearest NLS office or to the main office in Del Mar, California will bring prompt response.

SPECIFICATIONS

RANGES:	±9.9999/99.999/999.99 Volts DC. AC measurements, ohms, and DC measurements to ±10V can be made using accessory NLS 1100 or 1200 Series Converters or low level measurements using NLS Model 1401, 140, or 144 Amplifiers.
DIGITS:	Five.
POLARITY CHANGE:	Automatic.
RANGE CHANGE:	Automatic
SPEED:	Average: under 600 millisec/reading.
	Worst Case: with range and polarity change: 3.5 sec/reading.

SPEED (CONT)	Best Case: approximately 0.02 seconds per digit increase in rightmost window.
ACCURACY:	±(0.01% of reading +0.001% of full scale).
INPUT RESISTANCE:	10 megohms.
COMMON MODE REJECTION:	106 DB, minimum at 60 CPS with 1000-ohm source imbalance.
SIGNAL MODE NOISE REJECTION:	30 DB, minimum at 60 CPS.
INPUT CONNECTIONS:	
VOLTS	Amphenol type 97-3102A-14S-2P-426 connector is used on the DVM. The mate is Amphenol 97-3106A-14S-2S-426. The input signal pair is not connected to outer box; signal low is isolated from inner box (see figure 2-3). Input can float to 1000 volts difference between inner and outer cases.
RATIO	Amphenol type 97-3102A-14S-1P-426 connector is used for external reference Mating connector is type 97-3106A-14S-1S-426 Yellow lead is connected to signal ground, red to +10 V reference, and black to -10 V reference.
REFERENCE VOLTAGE SOURCE:	Internal, matched Zener diodes provide the digital potentiometer excitation voltage. Temperature control with an oven is not required.
DIMENSIONS:	5-1/2 inches high, 16 inches deep (excluding connectors and fan), 19 inches wide.
WEIGHT:	Approximately 37 pounds.
POWER SOURCE:	115 volts, 50-60 CPS, 60 watts maximum power consumption. For 230 volt operation, the two primary windings of the power transformer must be wired in series instead of in parallel.

Specifications subject to change without notice.

CHAPTER II

INSTALLATION AND OPERATION

UNPACKING

The instrument is shipped in a two-piece polystyrene-bead container. Cut the tape between the container halves and open. If damage is seen, promptly notify the carrier. No packing materials are used inside of the instrument and it is ready for use when taken out of the shipping container. It is suggested that the container be saved if the instrument is to be stored or shipped.

POWER SOURCE

The instrument is usually supplied for operation from 115-volt, 50-60 cycle power sources. However, the instrument will operate from 220-230 volt, 50-60 cycle sources if the two primaries of the power transformer are wired in series instead of in parallel. The Serial No. tag at the rear of the instrument indicates the correct power source if other than 115 volts.

FUSING

The instrument is protected by a 3AG one ampere slo-blo fuse which is located in an extractor post on the rear panel. When a 220-230 volt power source is to be used (and the power transformer primary rewired as indicated above), it is recommended that a half-ampere fuse be used to provide maximum protection. Keep in mind that the cooling fan is rated at 115 volts AC and must be paralleled with one winding of the power transformer pin connections when adapting the instrument to 230-volt operation.

POWER GROUNDING

The third pin of the power plug grounds the outer chassis of the instrument (figure 2-1). The internal guard shield box has no connection with power ground.

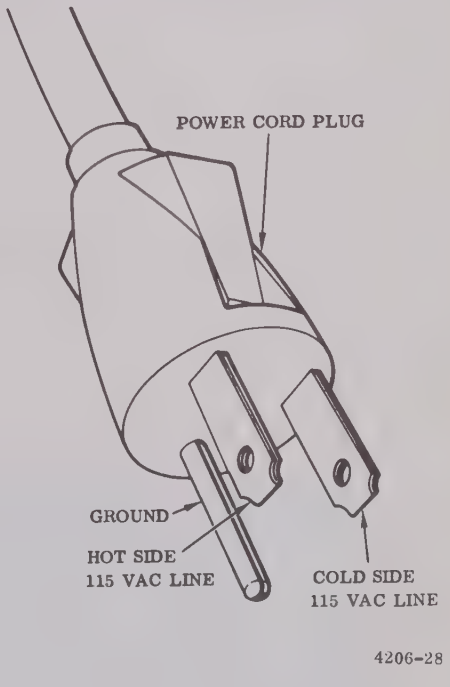


Figure 2-1. Power Plug Pin Coding

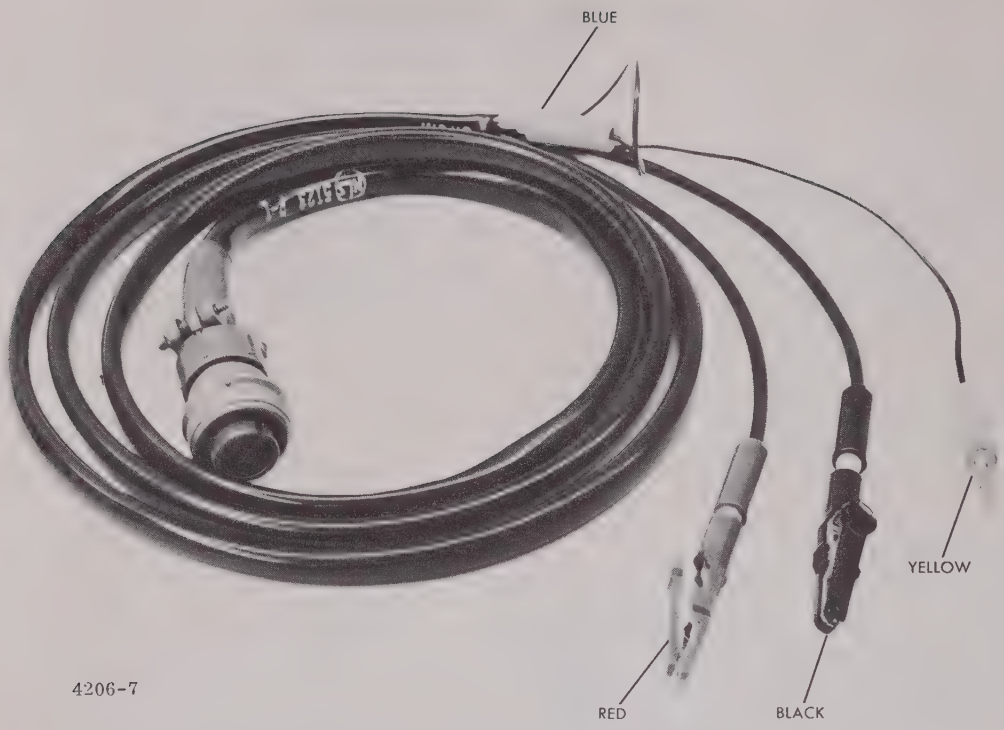


Figure 2-2. Cable Assembly

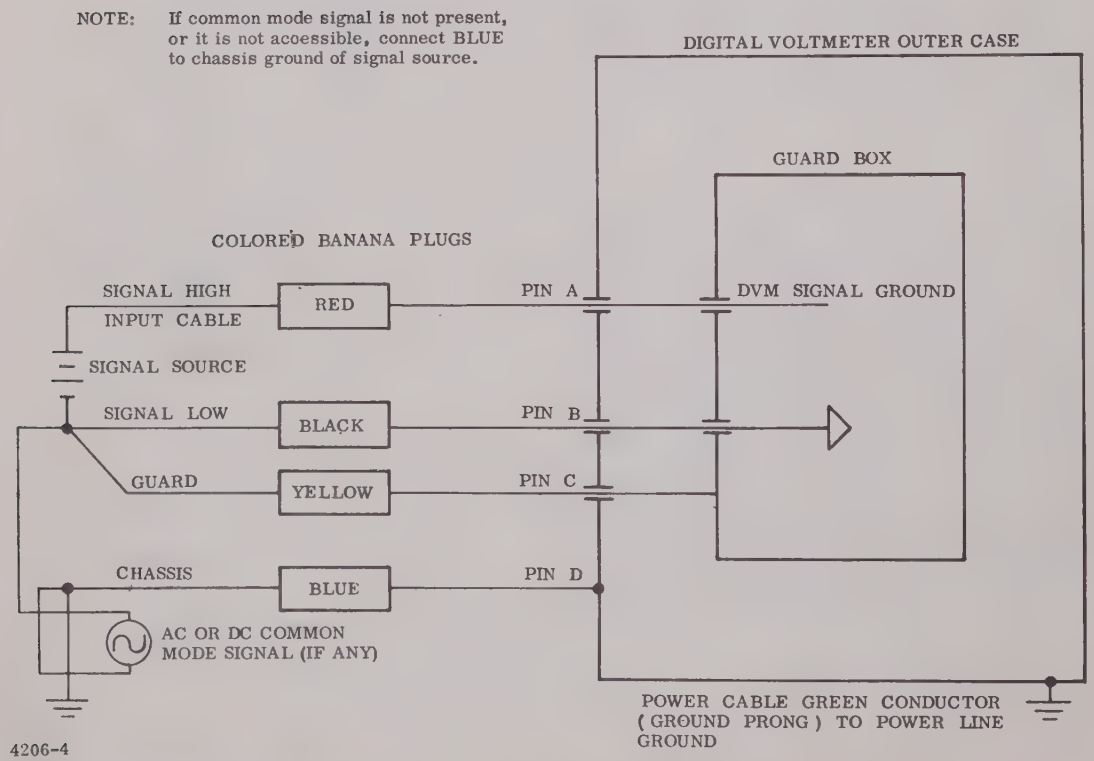


Figure 2-3. Input Connections

Figure 2-4. Front View

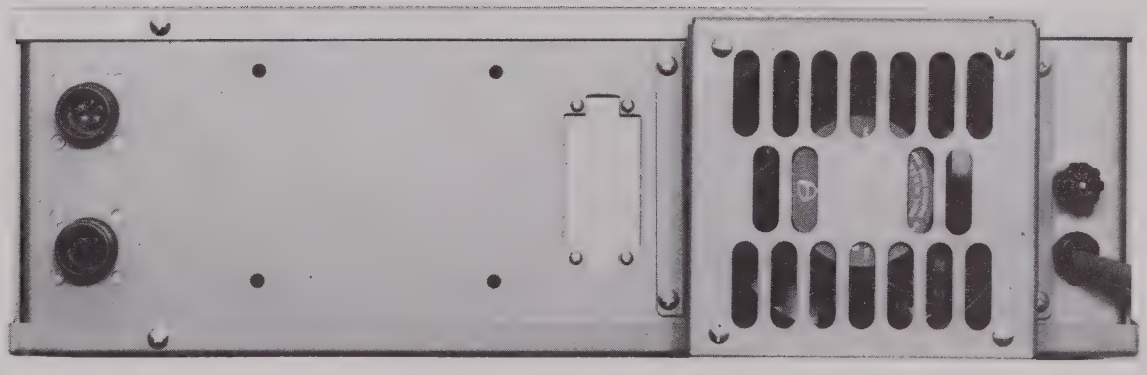


Figure 2-5. Rear View

CABLES

The instrument is supplied with two input cables, one for voltage measurement and one for measurement of ratio (figure 2-2). See figure 2-3 for connection information. The banana plugs on the cable are color coded.

Voltage Measurement (5123)

Pin A - red plug - signal high
Pin B - black plug - signal low
Pin C - yellow plug - inner guard shield of DVM
Pin D - blue plug - outer case of DVM.

Ratio Measurement (5124)

Pin A - red, + reference
Pin B - black, - reference
Pin C - yellow, signal ground
Pin D - blue, guard shield

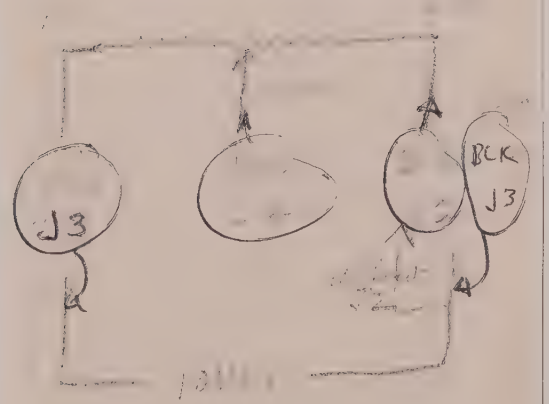
CONTROLS

The power switch is provided to supply to and remove a current from the instrument and to allow a warm-up position (STANDBY). The power switch also provides three positions (AUTO, CONT, MANUAL) for use if the optional print-out capability is desired. If the print-out capability is not elected, these positions are locked out.

The SENSITIVITY switch is provided to decrease sensitivity for noisy signals.

The FILTER switch is provided to engage or remove the filter application.

The FUNCTION switch is provided to allow the selection of voltage or ratio measurements.



CHAPTER III

THEORY OF OPERATION

A simplified block diagram of the Model 5015, showing signal flow paths among the major functional blocks, will be found in figure 3-1. Schematic diagrams of each printed circuit board assembly and the main board assembly wiring diagram will be found in numerical sequence at the end of this manual.

BASIC THEORY

When a DC signal voltage is applied to the input connector of the instrument, it is impressed across a 10 megohm range divider. If the signal is between zero and 9.9999 volts in value, and the range divider is set in the 10-volt range, the signal passes on to the error amplifier where it is compared with the feedback voltage. If the range divider is set in either the 100-volt or 1000-volt range, the unit will automatically downrange to the 10-volt range.

The DC signal input, within the error amplifier, is compared potentiometrically with the feedback voltage which is derived from a precision resistance bridge of five decades, automatically controlled by counters and relay logic. The five decades divide down a precision reference voltage of 10 volts to steps of 100 microvolts each. Threshold circuits in the error amplifier sense when the signal input and the feedback voltage differ by 100 microvolts or greater. If the signal input is greater than the feedback voltage, up-pulses are generated. If it is less, down-pulses are generated.

These pulses are routed through a polarity switch and into the counting decades through the associated decades relay logic. Relay logic determines when the count of either up- or down-pulses is transferred to the following decades. Relay logic also controls the resistance decades.

Up-pulses cause the counting decades to advance in count and the precision voltage divider output (feedback voltage) to increase. Down-pulses reset the counting decades to zero and cause the feedback voltage to go to zero. Relay logic is arranged so that up-pulses are routed through decade 1 first and then on to decades 2, 3, 4 and 5 as required. Down-pulses cause the decades to reset to zero (both digital display and feedback voltage) in a logical sequence, always starting with decade 1. Thus, the relay logic allows the DVM to generate precision feedback voltage in a logical fashion until it equals the DC signal input voltage within a resolution of 100 microvolts.

Polarity control is accomplished by means of a polarity flip-flop and two polarity relays. One polarity relay inverts the reference, the other interchanges the up- and down-pulse lines. A polarity trigger from the relay logic sets the polarity flip-flop whenever a change in polarity is required. This will occur when all decades have been reset to zero and down-pulses continue to be generated. The first down-pulse, after all decades have been reset to zero, becomes the polarity trigger.

The range divider is designed to attenuate the DC signal input by x10 and x100 as required. It is controlled by down-ranging logic, range flip-flop 1, range flip-flop 2 and a range decode matrix. The range flip-flops require two signals, up-range trigger and down-range reset. The range flip-flops and decode matrix select one of the three range conditions; i.e. 10V, 100V, or 1000V range. Buffers are used to drive range relays and decimal lamps. Down-ranging logic senses a unique set of conditions which occurs only when a lower range setting of the range divider is needed. It then generates the down-range trigger pulse. An up-trigger pulse is generated when the decades have been driven to all nines and up-pulses continue to be generated. The first up-pulse, after the decades are all nines, becomes an up-range trigger pulse. Up-range trigger pulses continue to occur until the correct range has been selected.

Chopper drive contains the primary synchronizing circuitry which operates the electro-mechanical chopper in the error amplifier and sends gating signals to Delay #1. Delay #1 synchronizes the generation of up- and down-pulses with chopper timing. Delay #2 receives gating signals from Delay #1. Delay #2 synchronizes the generation of the down-range trigger pulses.

INPUT SIGNAL FILTER

A simple double RC, low pass filter is provided to attenuate noise which may be superimposed on the DC signal. Attenuation at 60 CPS is 30 DB. The filter capacitors are high quality mylar units noted for their stability and freedom from dielectric soak.

WARNING

Do not disconnect voltmeter input leads from DC source when measuring voltages in the 100V to 1000V range. The filter capacitors will remain charged to these dangerous levels for considerable lengths of time if the input is opened. The Digital Voltmeter should be ranged down to the basic range after measuring high voltages before being disconnected from the source.

The filter may be removed from the input circuit by means of a switch on the front panel. If the filter is switched out, there is no danger from electrical shock as mentioned in the warning above.

RANGE ATTENUATOR

The range attenuator is an automatically operated voltage divider controlled by ranging logic in the logic assembly. The attenuator and associated range relays are located on the amplifier assembly to keep signal paths between the attenuator and the error comparator as short as possible.

The attenuator consists of seven NLS PW 2016 precision wire-wound resistors and two multiple-turn trimpots. See Schematic Diagram 50-177. The total resistance of the divider is 10.0011 megohms which provides a nominal input resistance of 10 megohms for the Digital Voltmeter.

Certain design considerations are paramount for this section of the amplifier as-

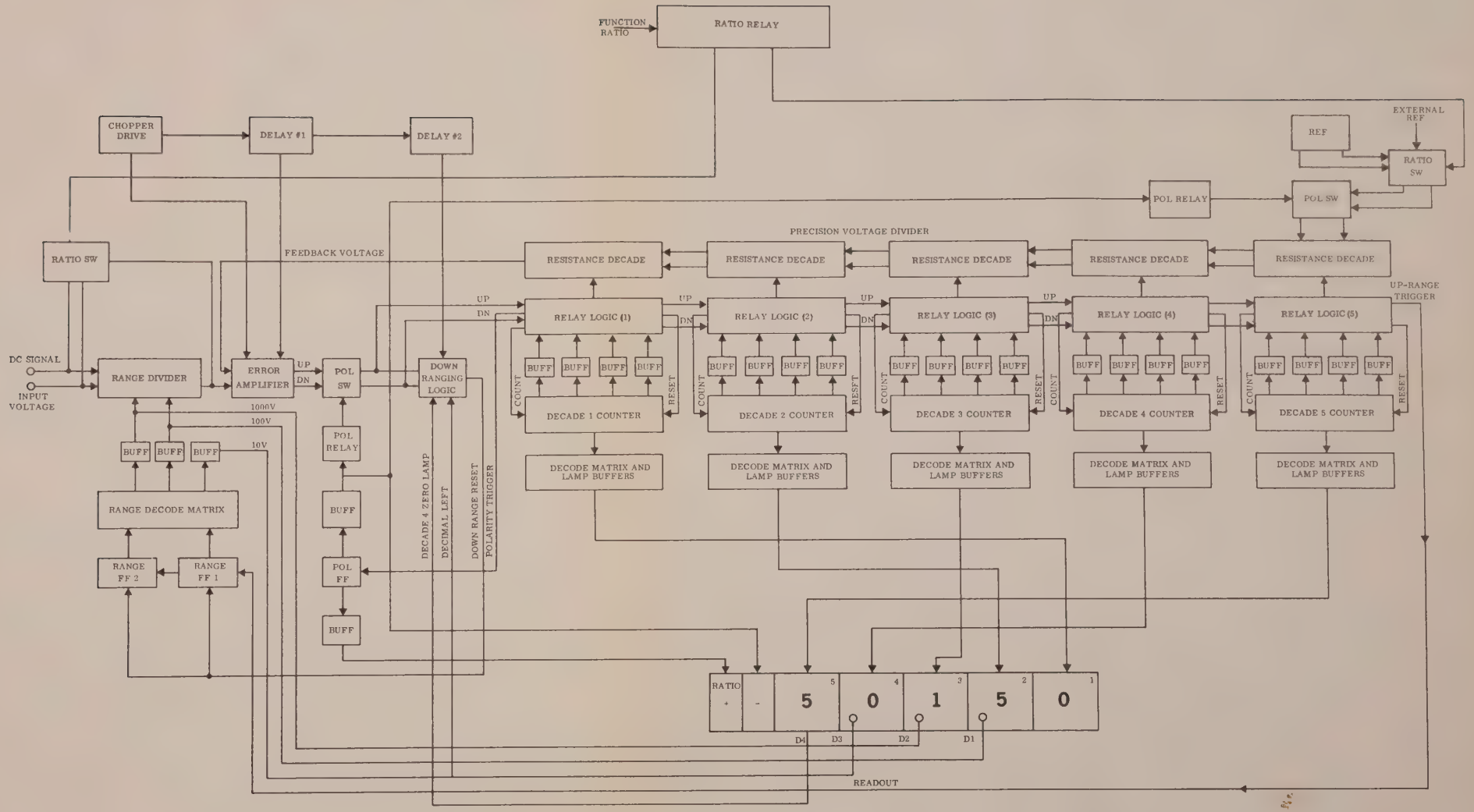


Figure 3-1. Simplified Block Diagram, Model 5015 DVM

sembly. Printed circuit layout and wiring is such that leakage from circuits carrying power supply levels to the attenuator is minimized as much as possible. Sealed range relays having high insulation resistance headers are used for range switching. The resistors are aged for stability and constructed to withstand high voltages. This area of the assembly must be kept as clean and free of organic and inorganic contaminants as is practically possible.

Range attenuator taps are selected by means of range logic in the logic assembly and range relays on the amplifier assembly. A simplified diagram of range logic is shown in figure 3-2. Figure 3-3 shows relay contact connections to the attenuator. Connections of the relay contacts to the divider are arranged so that up to four ranges may be selected with two relays. Only three range taps are used in the Model 5015 Digital Voltmeter.

RANGE ATTENUATOR OPERATION

Range relays K4 and K5 are normally de-energized when the Digital Voltmeter is reading in the basic 10V range. The DC input voltage path may be traced through R15 and R14 of the input filter, R20, the closed contacts 1 and 3 of relay K4 and the closed contacts 1 and 3 of relay K5 on to the output (see figure 3-3). The range attenuator and range relays are located on the 50-177 amplifier assembly. Range logic circuitry is located on the 50-192 logic assembly.

For operation on the 100V range, relay K5 is pulled in. The transfer of wiper 3 of K5 from pin 1 to pin 5 opens the 10V range path and connects the 100V tap to the divider output.

For operation on the 1000V range, relay K5 is de-energized and relay K4 pulled in. Drop-out of relay K5 disconnects the 100V tap from the range divider output. Pull-in of relay K4 opens the 10V range path and connects the 1000V tap to the range divider output. The signal passes through R21, closed contacts 6 and 8 of relay K5, closed contacts 3 and 5 of relay K4, and finally closed contacts 1 and 3 of relay K5.

ERROR COMPARATOR

The elements of the error comparator are shown in figure 3-4.

Error comparison is done electromechanically by utilizing a Bristol CH-1417-27 Synchroverter driven at a chopping rate of approximately 40 CPS. Adherence to an exact frequency is unimportant since all timing functions are synchronized to the multivibrator in the logic assembly which drives the chopper coil.

When the chopper wiper dwells on pin 2, capacitor C3 charges through 910K to a voltage level proportional to e_D, the input voltage. When the wiper dwells on pin 4, the voltage on C3 must re-adjust by charging or discharging, as the case may be, to the Digital Voltmeter feedback voltage Level e_f. This results in a square wave voltage waveform at pin 3 having the approximate shape illustrated in figure 3-5.

This waveform is differentiated by capacitor C3 and resistor R10 in the linear pulse amplifier to produce short duration voltage pulses whose amplitude is proportional to the difference between e_D and e_f.

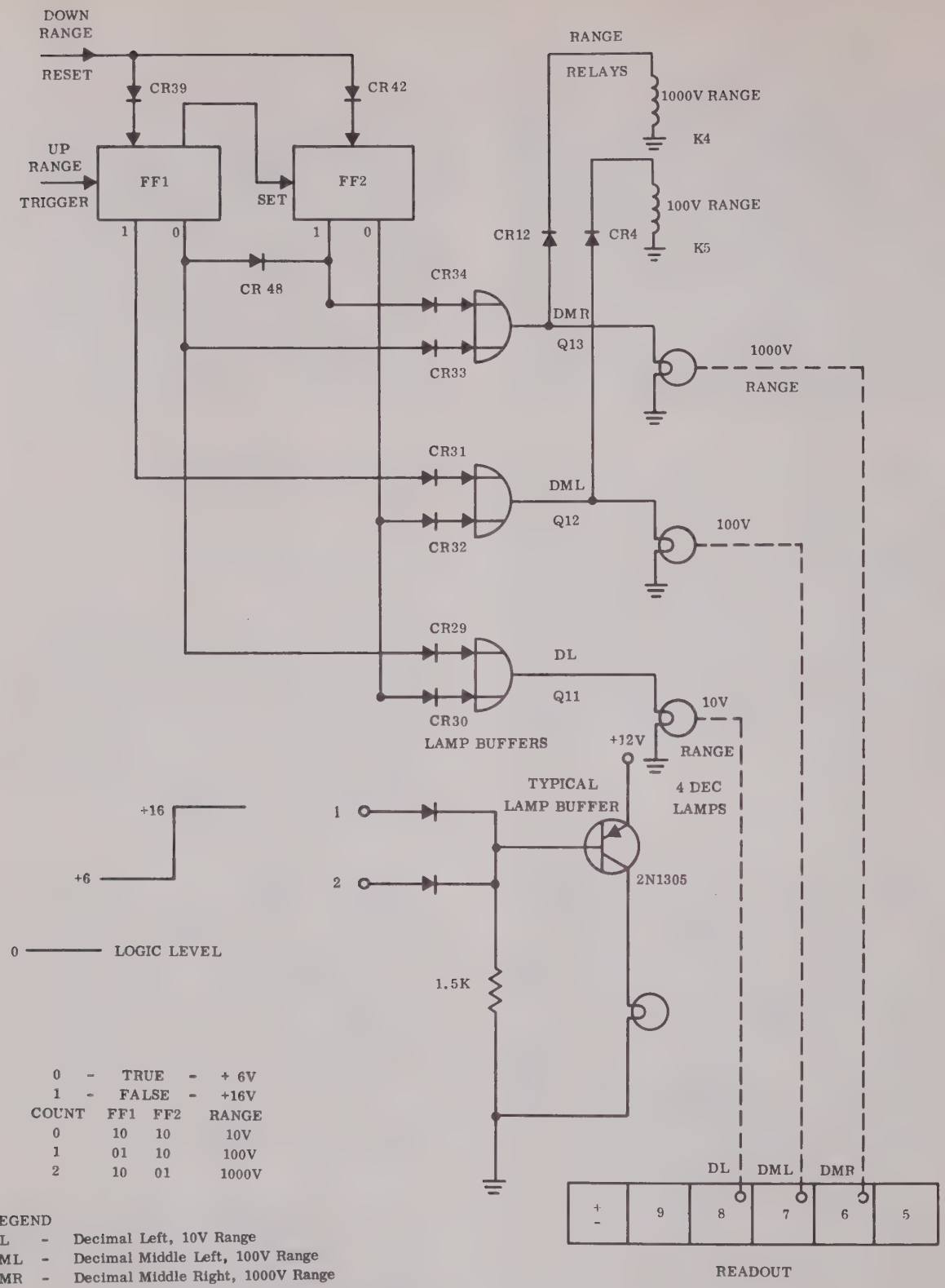
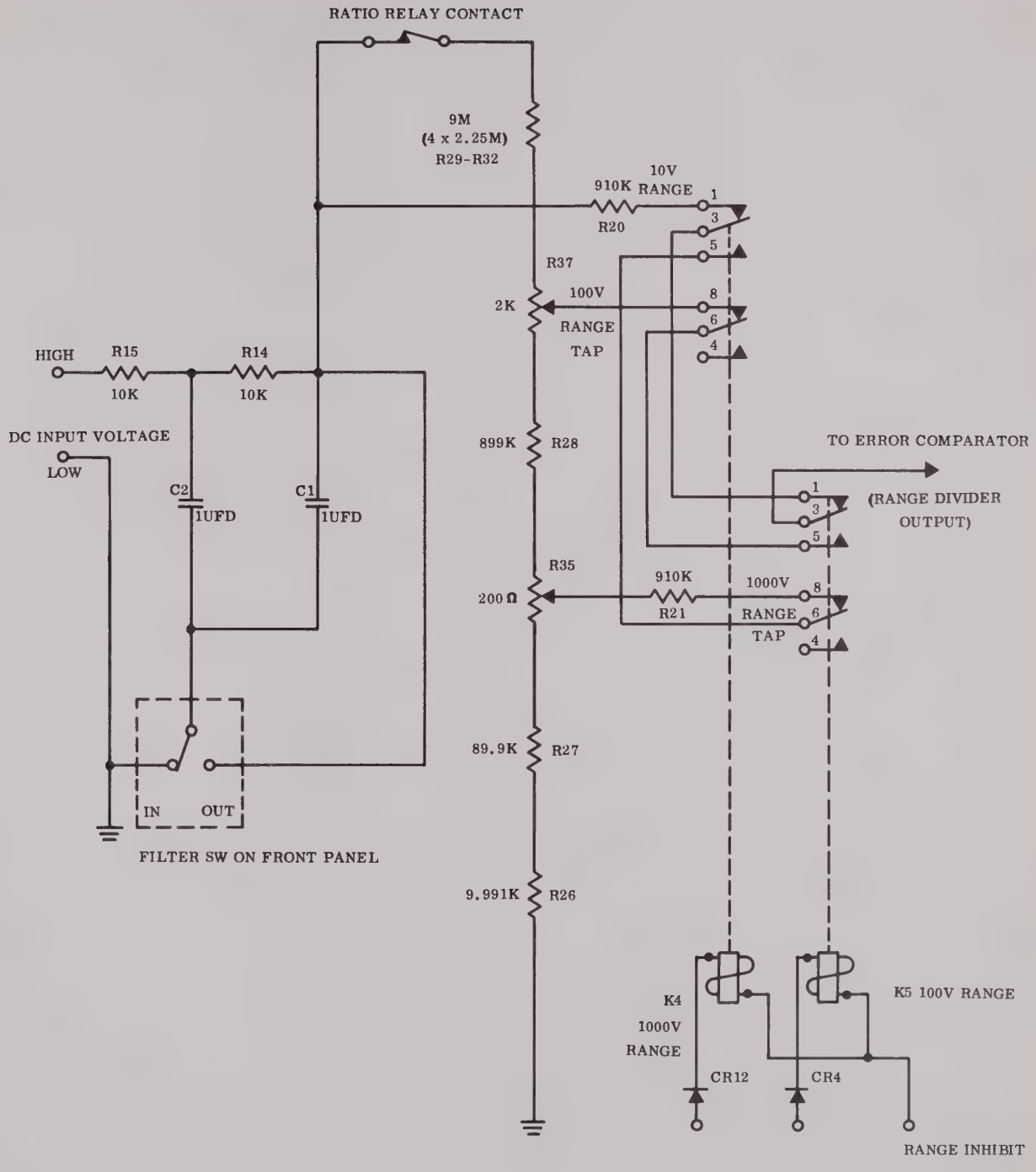
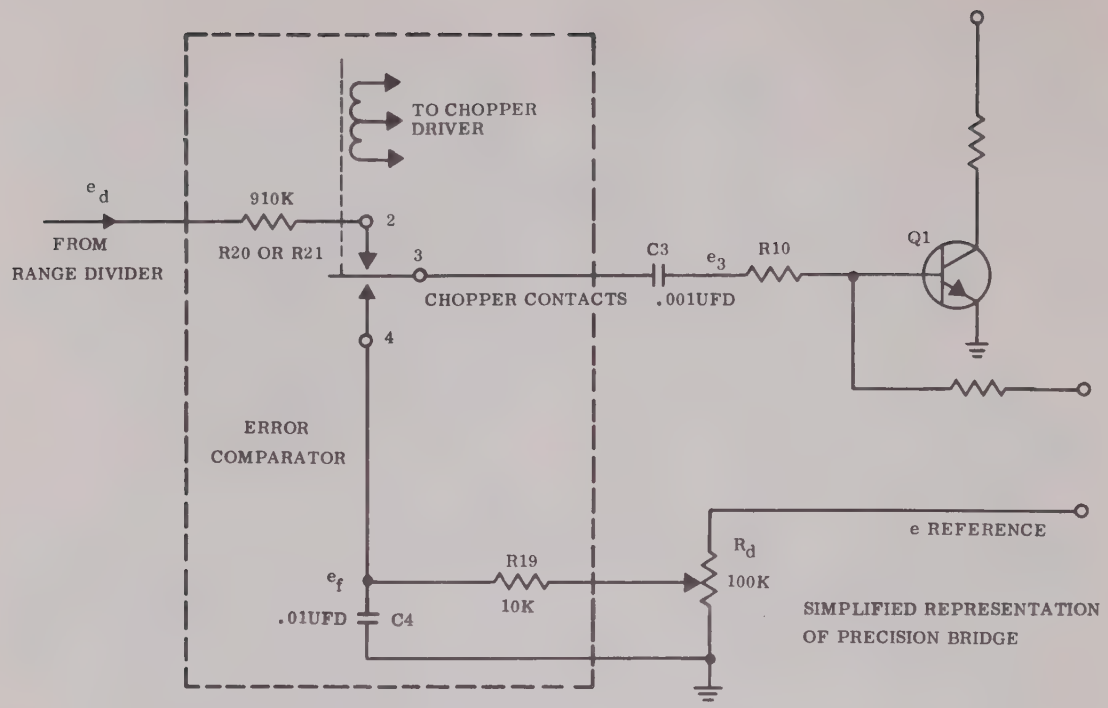


Figure 3-2. Range Logic Simplified Schematic Diagram



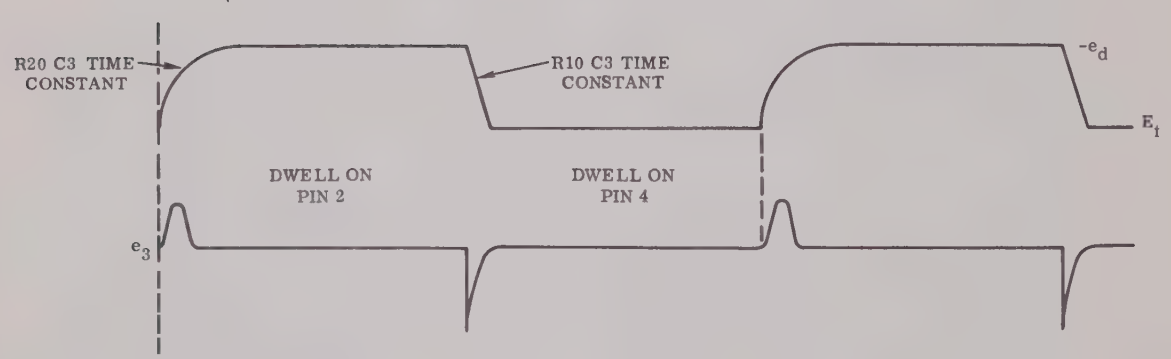
5015-6

Figure 3-3. Attenuator Relay Contact Connections Schematic Diagram



5015-8

Figure 3-4. Error Comparator Simplified Schematic Diagram



5015-3

Figure 3-5. Error Comparator Voltage Waveform

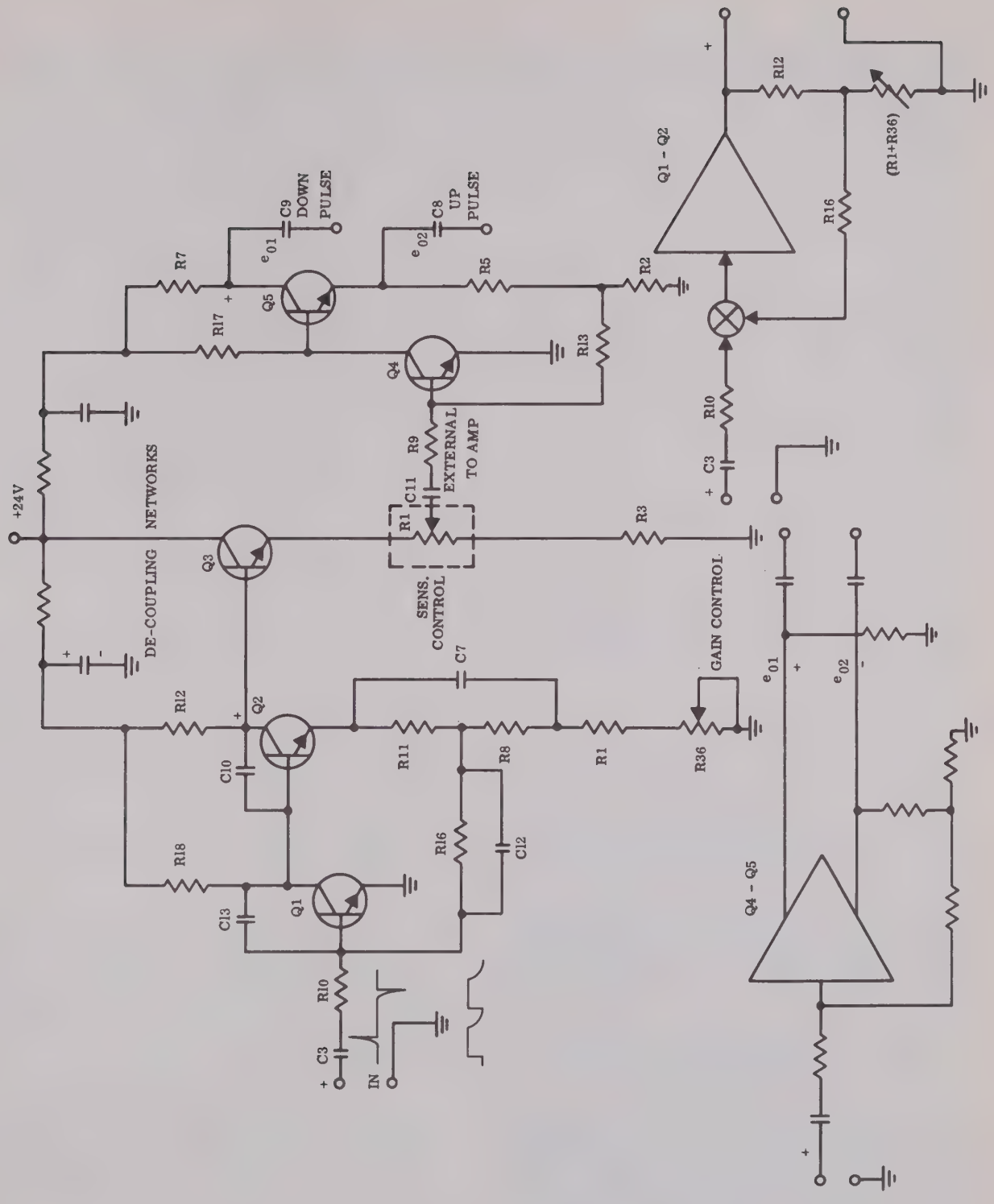


Figure 3-6. Linear Pulse Amplifier Simplified Schematic Diagram

The low frequency cutoff of the linear pulse amplifier is adjusted so that the change in voltage at pin 3 produced by the relatively slow time constant R20 • C3 is severely attenuated (when chopper wiper dwells on pin 2). The change in voltage at pin 3 produced by the fast time constant R10 • C3 is essentially not attenuated by the amplifier (chopper wiper dwells on pin 4). Only the pulse produced when the chopper wiper dwells on pin 4 is used for error sensing purposes. All phasing in the Digital Voltmeter having to do with error pulse conditioning and generation of up- and down-pulses is based on this fact.

Capacitor C4 serves as a source of charge which allows capacitor C3 to change its charge level rapidly. Resistor R19 in combination with C4 forms a simple low pass RC filter which aids in attenuating switching noise coming from the precision bridge.

The 910K resistor shown in the diagram may be either R20 or R21 in the amplifier assembly, see Schematic 50-177. Its purpose is to maintain essentially constant source impedance to the error comparator when the Digital Voltmeter is operating on the basic 10V range or the 1000V range. This matches the source resistance of the range divider on the 100V range (approximately 910K).

ERROR COMPARATOR - LINEAR PULSE AMPLIFIER OPERATION

Assume that the input from the range attenuator, e_D, is positive with respect to the Digital Voltmeter feedback voltage, e_f. (See figures 3-4, 3-5, 3-6 as required.) When the chopper wiper dwells on pin 2, a positive-going pulse is produced at the junction of R10 and C3. This pulse is not used. When the chopper wiper dwells on pin 4, a negative-going pulse is produced. If the difference between e_d and e_f is greater than 100 microvolts, the precision bridge must be signalled to automatically adjust its output upward or in a positive direction. Following the polarity marks shown in figure 3-5, it can be seen that an amplified negative-going pulse will appear at the collector of Q5 and a positive-going pulse at the emitter of Q5. There is a further restriction that only positive-going pulses can trigger the threshold detector circuits. Therefore the up-pulse line of the linear pulse amplifier is identified as the output at the emitter of Q5. The down-pulse line is then the output at the collector of Q5.

The transistor circuitry in the linear pulse amplifier requires a collector supply of +24 (±1 VDC) at a current drain of about 20 ma. De-coupling networks isolate the transistor-feedback pairs from the common power supply impedance.

LINEAR PULSE AMPLIFIER

The purpose of the linear pulse amplifier is to amplify the level of the error signal coming from the error comparator to a magnitude of approximately one volt. One volt is the trigger level of the threshold detector circuits in the logic assembly.

The AC gain of the linear pulse amplifier is set and controlled by three feedback amplifiers. The first consists of transistor-feedback pair, Q1 and Q2; the second is an emitter follower, Q3; and the third is made

up of transistor-feedback pair, Q4 and Q5. Feedback pair, Q1 - Q2, and, Q4 - Q5 are similar in design except that feedback pair, Q4 - Q5 has been modified to provide a split phase output. High beta low noise silicon transistors are used throughout.

By treating the two-transistor-feedback pair as a building block, a high gain amplifier has been constructed which offers excellent bandwidth at low noise levels, midband gain predictability, and economy of components; and because of its direct-coupled arrangement, excellent bias stability.

A simplified diagram of the two-transistor-feedback amplifier is shown in figure 3-7(A). All capacitors except input capacitor C3 and emitter bypass capacitor C7 have been omitted for simplicity.

Plus and minus signs indicate instantaneous signal polarities. The circuit is further simplified in figure 3-7(B) and 3-7(C) by assuming C7 adequately bypasses R11 and R8 in the frequency range of interest and that the current gains of Q1 and Q2 are high.

The base of Q1 serves as a summing junction for the input voltage and negative feedback obtained through resistor R16. This type of connection is called parallel feedback and causes the input resistance at midband to become essentially R10. An analysis of this circuit, using conventional techniques, yields the following approximate expression for voltage gain:

$$\frac{e_o}{e_i} = \frac{R12}{R1 + R36} \cdot \frac{R16}{R10}$$

Thus the range of gains available in this section of the amplifier is as follows:

R10 = 1K R12 = 6.8K R36 = 0

R16 = 12K R1 = 30 ohms

$$\frac{e_o}{e_i} = \frac{R12}{R1} \cdot \frac{R16}{R10} = \frac{6800}{30} \cdot \frac{12000}{1000}$$

$$\frac{e_o}{e_i} = 2720$$

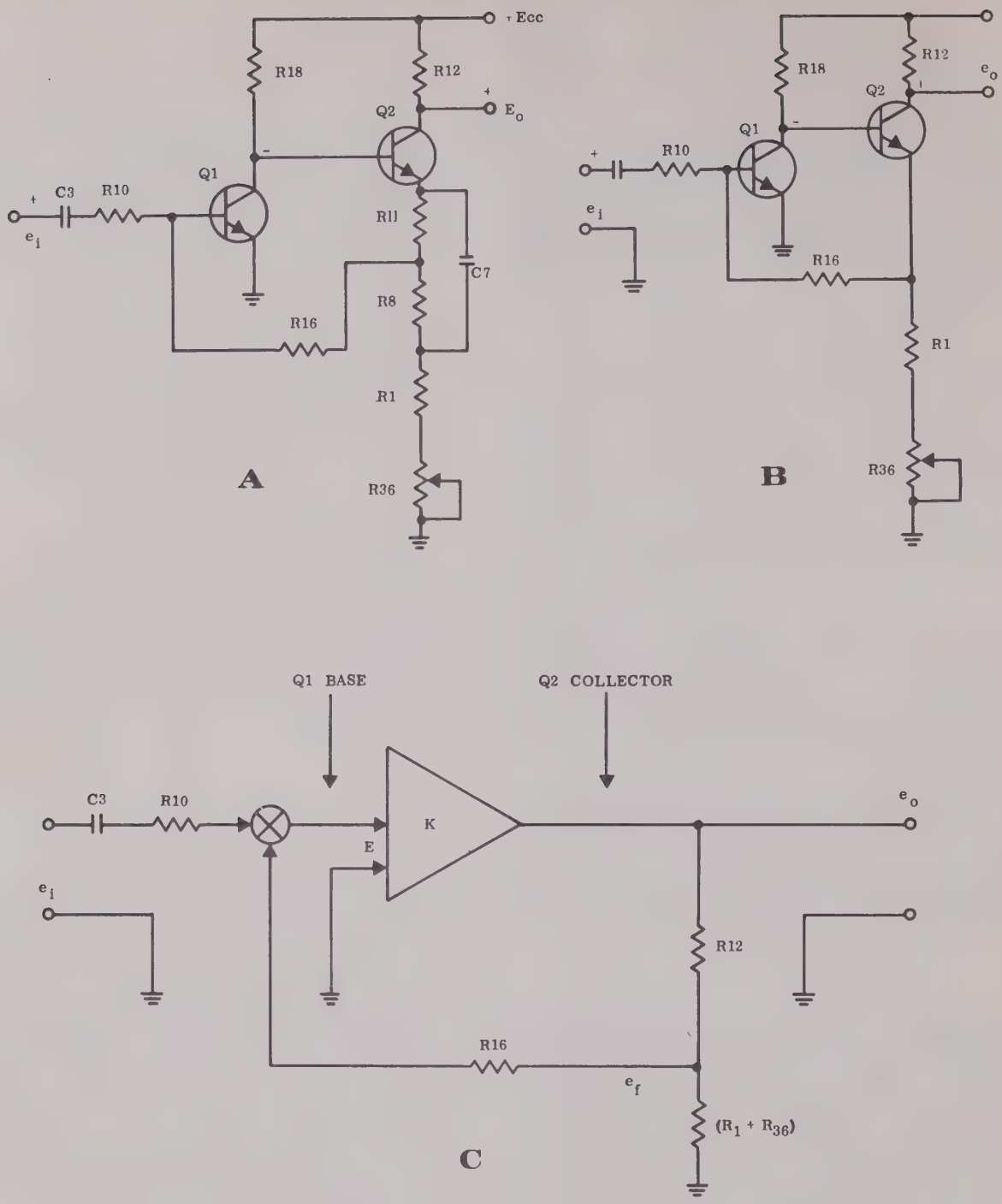
For R36 = 200

$$\frac{e_o}{e_i} = \frac{6800}{230} \cdot 12$$

$$\frac{e_o}{e_i} = 354$$

By adjusting R36 the gain may be varied over the range 354-2720.

DC feedback for bias-point stability is obtained from a divider consisting of resistors R11, R8, R1, and R36 in the emitter circuit of Q2. Resistor R10 does not affect DC feedback to the base of Q1 because capacitor C3 blocks any DC return path to ground. Because of this, resistor R10 may conveniently be used to change the AC gain of the feedback pair by a large amount without affecting the DC biasing of the amplifier. Capacitors C10, C12, and C13 are used to roll-off the high frequency gain of the amplifier. See Figure 3-6.



5015-11

Figure 3-7 Two-Transistor Feedback Amplifier Simplified Schematic Diagram

Transistor Q3, resistor R3 and sensitivity control R1 comprise an emitter follower which buffers the output of the Q1 - Q2 feedback pair from the input of the Q4 - Q5 feedback pair. It also provides a convenient point to insert the Digital Voltmeter sensitivity control at a higher signal level to minimize noise pickup in the wiring going to the sensitivity potentiometer R1. Its gain is unity with R1 turned fully counterclockwise. When R1 is fully clockwise the gain is approximately

$$\frac{180}{180 + 1000} = \frac{180}{1180} = 0.16$$

Therefore this control can reduce the sensitivity of the pulse amplifier by a factor of $\frac{1}{0.15} = 6.7$. In terms of digits of sensitivity this would be about 6-7 digits.

The output stage of the Q4 - Q5 feedback pair has been altered to provide a split phase output, i.e., signals of equal magnitude, but opposite phase, are seen at the dual outputs. See Figure 3-8.

Plus and minus signs indicate instantaneous signal polarities. Using conventional analysis techniques, the gain derivation for the dual outputs produced the following approximate expressions:

$$\frac{e_{01}}{e_i} = \frac{R7}{R2} \cdot \frac{R13}{R9}$$

$$\frac{e_{02}}{e_i} = \frac{R5}{R2} \cdot \frac{R13}{R9}$$

The gains are equal but opposite in phase. A typical value of gain then is:

$$\frac{e_{01}}{e_i} = \frac{360}{36} \cdot \frac{10,000}{1000}$$

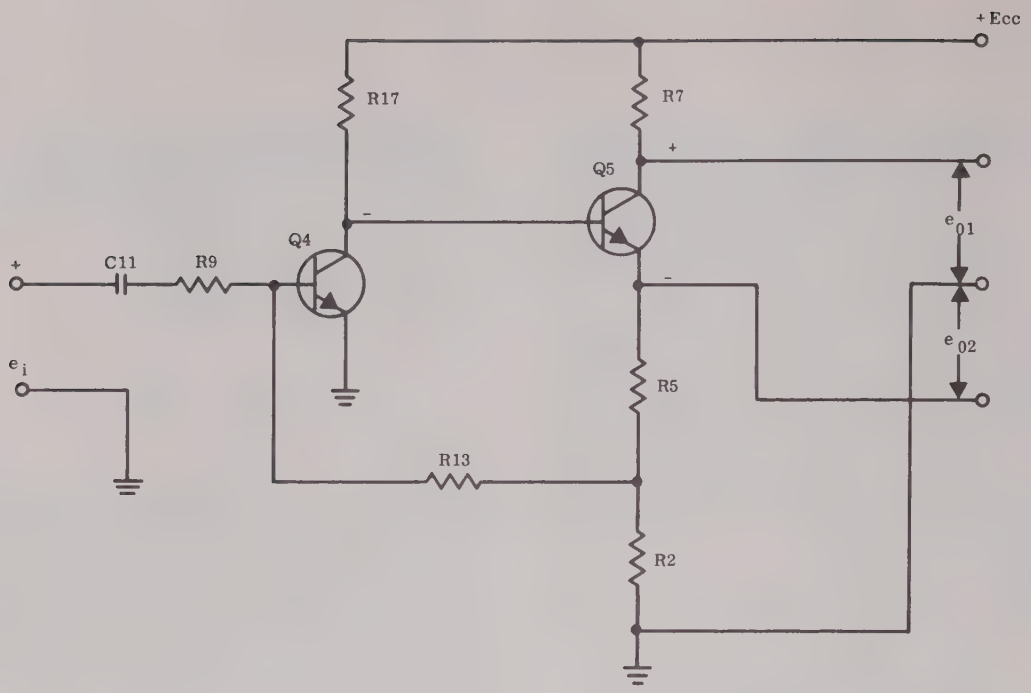
$$= 10 \cdot 10 = 100$$

Thus, the product of gains of the two feedback pairs and emitter follower (with gain of unity) can vary over the range of 3540 to 27,200. This is then adequate to provide the gain of 10,000, required to raise a 100 microvolt error, the basic sensitivity of the Digital Voltmeter, to 1.0 volts. Pulses identified as up- and down-pulses are coupled from the dual output of transistor Q5 through capacitors C8 and C9 (see figure 3-6) to the threshold detection circuits in the Logic Assembly.

THRESHOLD DETECTOR

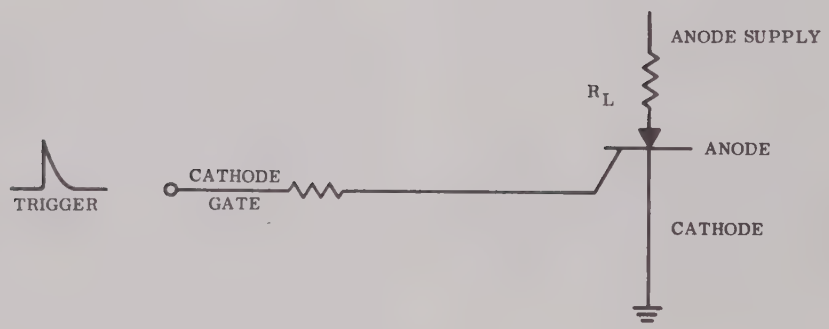
The up-and-down pulse lines are routed to two identical threshold detection circuits. The primary purpose of the threshold detector is to sense when an error pulse amplitude, corresponding to a 100 microvolt difference at the output of the error comparator, is exceeded. This amplitude is approximately 1.0 volt. In addition, the detector must raise the power level of the amplifier output to generate:

1. Up- and down-triggers for the decade counters.
2. Synchronize these triggers with the chopper drive.
3. Prevent cross-coupling between up and down channels.



5015-5

Figure 3-8. Output Stage Schematic Diagram



5015-10

Figure 3-9. Example of Silicon-Controlled Switch Circuit

4. Blank out noise generated by the chopper, logic circuits and relay logic.

The design of the threshold detector is based on the characteristics of the 3N58 silicon-controlled-switch (SCS). This thyratron-like device is similar to silicon controlled rectifiers but is designed to operate at lower power levels (see figure 3-9).

The characteristics of importance of the threshold detector are:

1. The device may be turned on by extremely low current and voltage levels at the cathode gate.
2. Once turned on, the device remains on until the anode supply is removed or the load current is reduced to a value less than the holding current of the device.

A diagram of the threshold detector is shown in figure 3-10.

The anode supply is a square wave of voltage obtained from the chopper drive circuitry. It varies between the levels of +2V and +20V.

Both Q25 and Q26 remain in a blocked state until either an up- or down-pulse of approximately 1.0 volts triggers one of them into the "on" state. The up- and down-pulses are synchronized and phased with the anode supply in such a way that the anodes of Q25 and Q26 are positive when the chopper wiper dwells on pin 4, the precision bridge feedback voltage. If Q25 is triggered into the "on" state, it saturates with a forward voltage drop of about 1.0 volt and current flows through the load circuit consisting of R20 and R3. The current is limited by the ohmic value of these resistors and by the +20 volt anode supply during one-half cycle of a clock period. The voltage drop across R3 reverse biases the cathode gate of Q26 to prevent it from being turned on by positive-going overshoots on the up-input. Thus, an important operating feature of the threshold detector is that whenever one of the silicon-controlled-switches is turned on, the other is biased off by the current flow of the "on"-switch through the common cathode resistor.

When the anode supply drops to +2V, an "on" SCS will turn off. During the half-cycle that a SCS is turned on, it cannot respond to any noise pulses at its cathode gate. When the SCS is off (anode supply at +2), it cannot be turned on by noise spikes. Figure 3-11 shows the timing relationships of the error pulses, anode supply and chopper drive (clock).

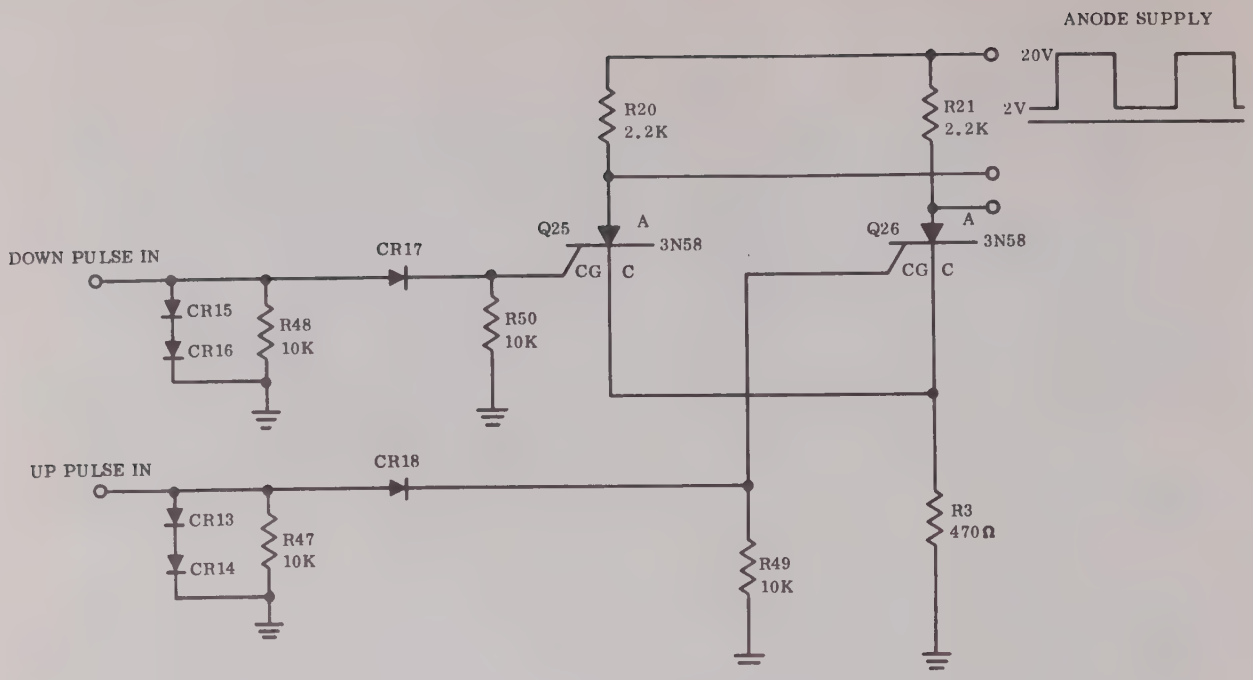
Delay No. 1 is approximately 150 microseconds. Mechanical and electrical delay of the chopper, T_c is about 300 microseconds.

The leading edge of the anode supply is delayed 150 microseconds to blank out chopper switching spikes.

RANGE LOGIC

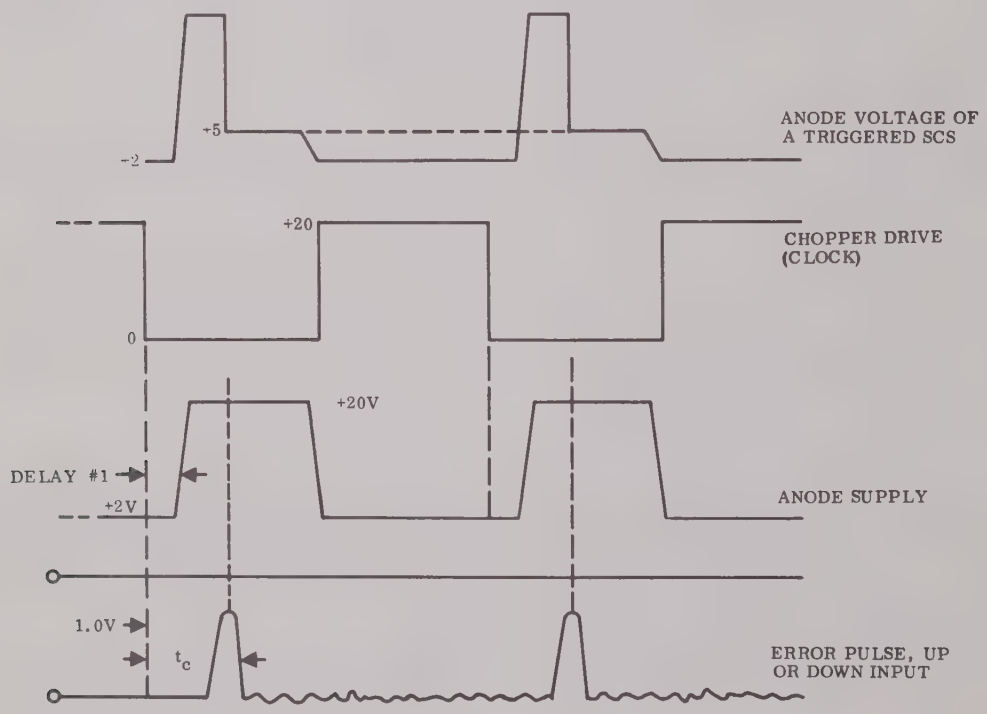
A simplified diagram of the range selection logic is shown in figure 3-2. Refer to Schematic Diagram 50-192 for circuit details.

A two-stage binary counter, six-diode decoding network and three buffer gates are



5015-9

Figure 3-10. Threshold Detector Schematic Diagram



5015-2

Figure 3-11. Threshold Detector Timing

required to permit automatic selection of range and decimal point. The purpose of the counter, decoding network and buffers is to select one of three range conditions, energize one of the three decimal lamps in the readout and operate range relays K4 and K5.

A truth table listing the logic level outputs of the flip-flops is shown in Figure 3-2 along with a typical circuit of the lamp and relay buffer.

The buffer operates as follows: if either input 1 or 2 has a logic 1 (+16V) applied, the 2N1305 is reverse biased and the decimal lamp is not energized. If inputs have a logic 0 (+6V) applied, the 2N1305 is forward biased into saturation and thereby energizes the lamp.

Reset of FF1 and FF2 puts the Digital Voltmeter in the 10V range. The logic diagram shows that logic 0 is applied to both inputs of "AND" gate Q11 causing it to energize the left-most decimal (DL). The other gates have a logic 1 applied to one of the two inputs and are consequently turned off.

The Digital Voltmeter will remain in the 10V range until the range counter receives a single up-range trigger pulse from the relay logic. This pulse sets FF1 causing the logic levels applied to "AND" gate Q12 to be logic 0. This gate turns on Decimal Middle Left (DML) and energizes relay K5. Pull-in of relay K5 places the range attenuator in the 100V range position.

A second up-range trigger pulse will be generated when operation in the 1000V range is required. This pulse resets FF1 and sets FF2. This state of logic conditions causes AND gate Q13 to turn on Decimal Middle Right (DMR) and pull-in relay K4. Logic states cause "AND" gate Q12 to turn off and "AND" gate Q11 to remain off. This places the range attenuator in the 1000V position. Diode CR48 prevents FFI and FF2 from being set simultaneously.

When ranging from either the 100V or 1000V range is required, a down-range reset pulse, generated in the logic assembly, resets FF1 and FF2 and places the Digital Voltmeter in the basic 10V range. If ranging from the 1000V range to the 100V range is required, the range logic will always reset to the basic 10V range and then up-range into the 100V range.

DECADE ASSEMBLY

A decade assembly contains the following functional circuits:

1. Relay logic,
2. A decade section of the precision resistance bridge,
3. Binary-to-decimal decoding matrix,
4. Readout lamp buffers,
5. Relay buffers, and
6. Decade counter.

This assembly converts the count of up- and down-pulses into analog voltage levels. Starting with the most significant decade, these voltage levels are transferred from decade to decade and divided by ten each time before being applied as feedback to one input of the error comparator.

Refer to schematic 50-114 for circuit reference designations. A decade counter consists of four cascaded binary flip-flops

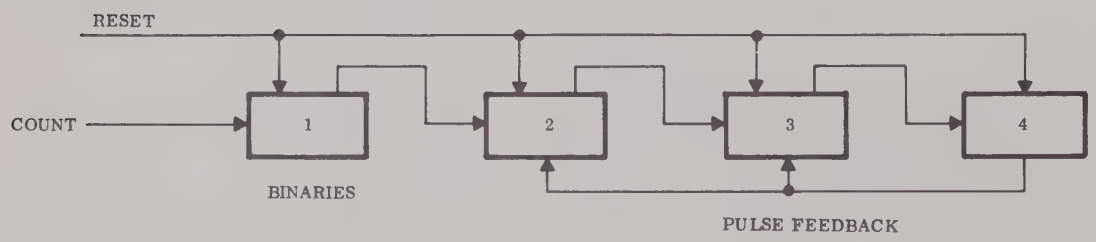
with pulse feedback from the 4th binary to both the 2nd and 3rd binaries. The pulse feedback causes the decade count to fall into correspondence with the basic bit code of the instrument, i.e., 1-2-4-2.*

The truth table of figure 3-12 shows the manner in which the count progresses in the counter and the particular bit of the 1-2-4-2* code associated with each binary. The 0 indicates the absence of a bit and 1, the insertion of a bit. The summation of the corresponding bits results in a total equal to the number of counts stored in the decade.

Physically, the insertion or removal of bits to produce an analog of the count is controlled by relay logic and a string of precision resistors connected as a Wolff-Pogendorf bridge. See figure 3-13.

The binaries associated with each bit of the code are also shown in simplified block diagram form.

This type of bridge connection always presents a constant resistance to the reference input (terminals A and B). Normally-open and normally-closed relay contact



COUNT	1	2	4	2*
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	1	1	1
9	1	1	1	1

5015-17

Figure 3-12. Truth Table for Decade Counter

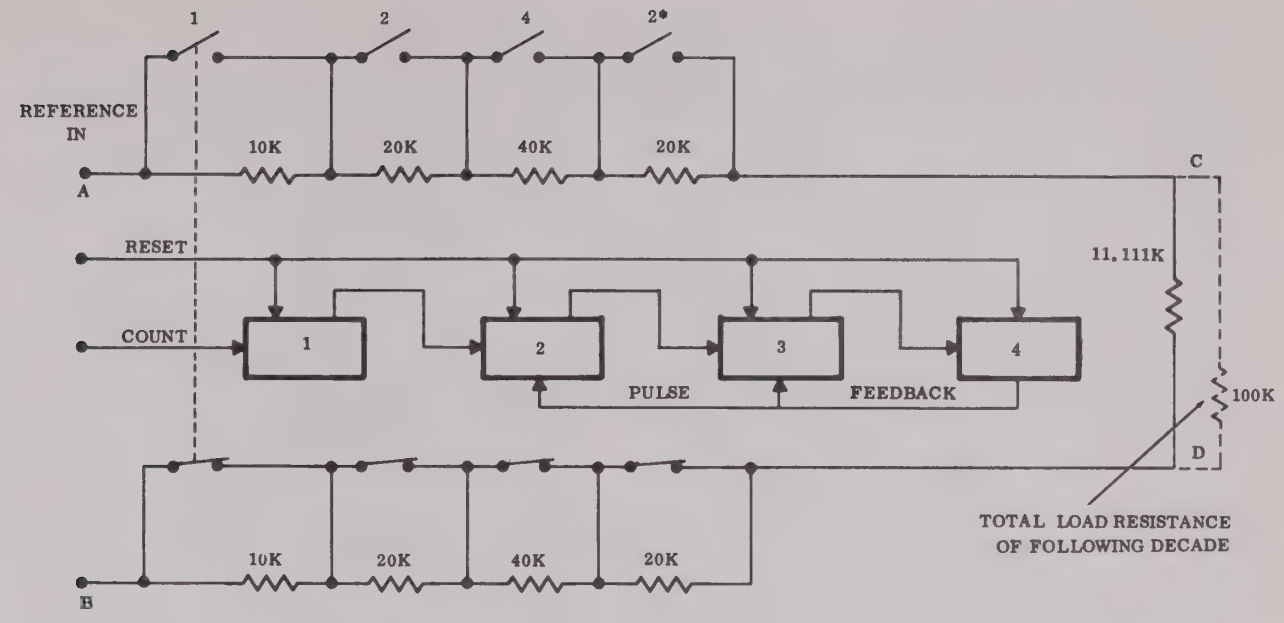


Figure 3-13. Wolff-Poggendorf Bridge Section

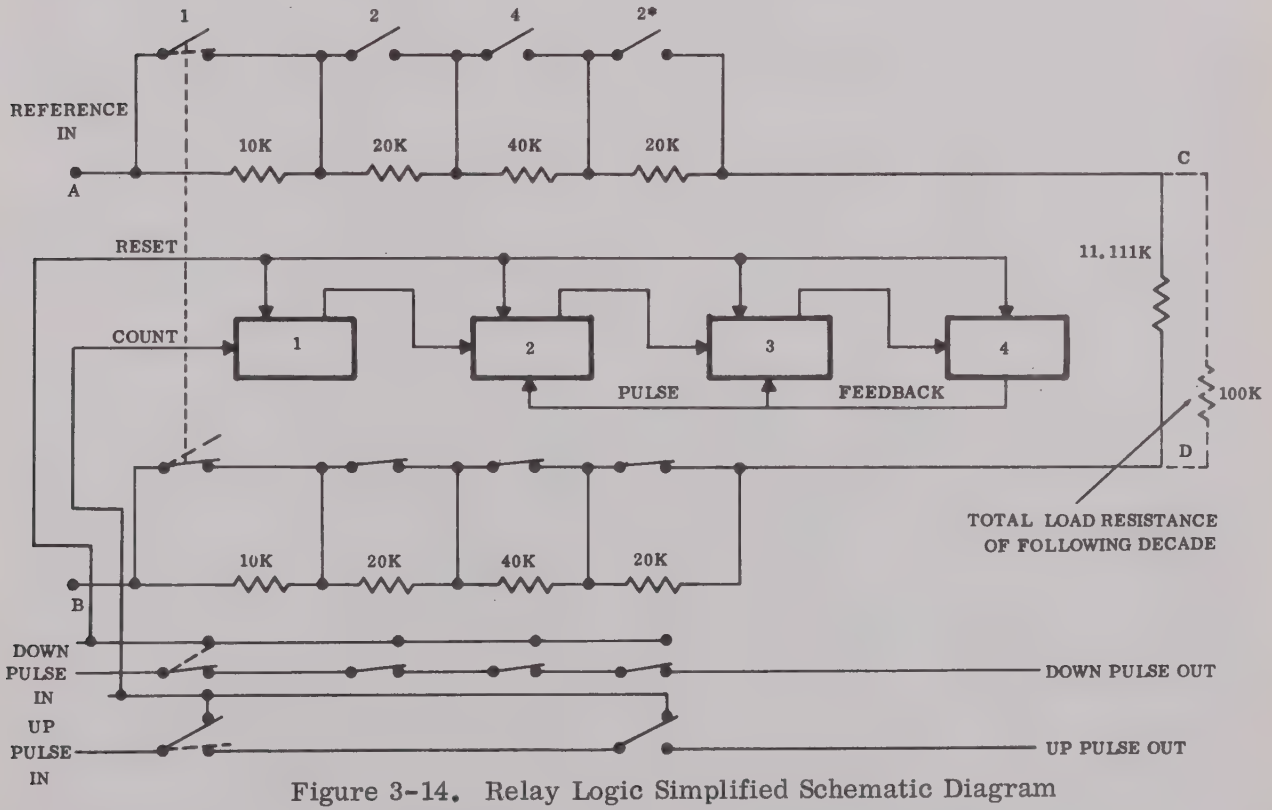


Figure 3-14. Relay Logic Simplified Schematic Diagram

pairs operate simultaneously to insert or remove resistors whose value is proportional to the bit code. The relay contacts are associated with relays that are driven by the buffered logic outputs from the counter binaries. The 11.111K terminating resistor in parallel with the 100K total resistance of the following bridge section results in 10K ohms across points C and D. This connection, called iso-ohmic, allows all decades to have the same value of resistors and to have identical input resistance no matter how many decades of division are used.

Assume a reference input of 10V. As the count progresses from 0 through 9 according to the truth table of figure 3-12, resistors in the upper and lower half of the divider are logically switched in and out by the relays. This produces an increasing voltage of 0 to 9 volts in 1 volt steps across points D and B, and 1 to 10 volts across points C and B. The Model 5015 has 5 such resistance decades in cascade. The first and least significant decade is terminated with a 100K resistor to simulate the total resistance of a decade which would normally follow.

Since the accuracy and linearity of the 5015 depend almost entirely on the 5th or most significant decade, these resistors are manufactured as a matched set. They are carefully assembled, aged and also matched for similar temperature coefficients. This decade is mechanically keyed so that it may not be interchanged with any of the other four.

RELAY LOGIC

Relay logic is used to control the routing of up and down pulses to the count and reset inputs of the decade counter. One relay is associated with each of the resistor pairs in the Wolff-Poggendorf bridge - four per decade. Each relay contains the normally open (form A), normally closed (form B) contacts which control the resistance bridge, and two form C contact assemblies for routing the up and down pulses.

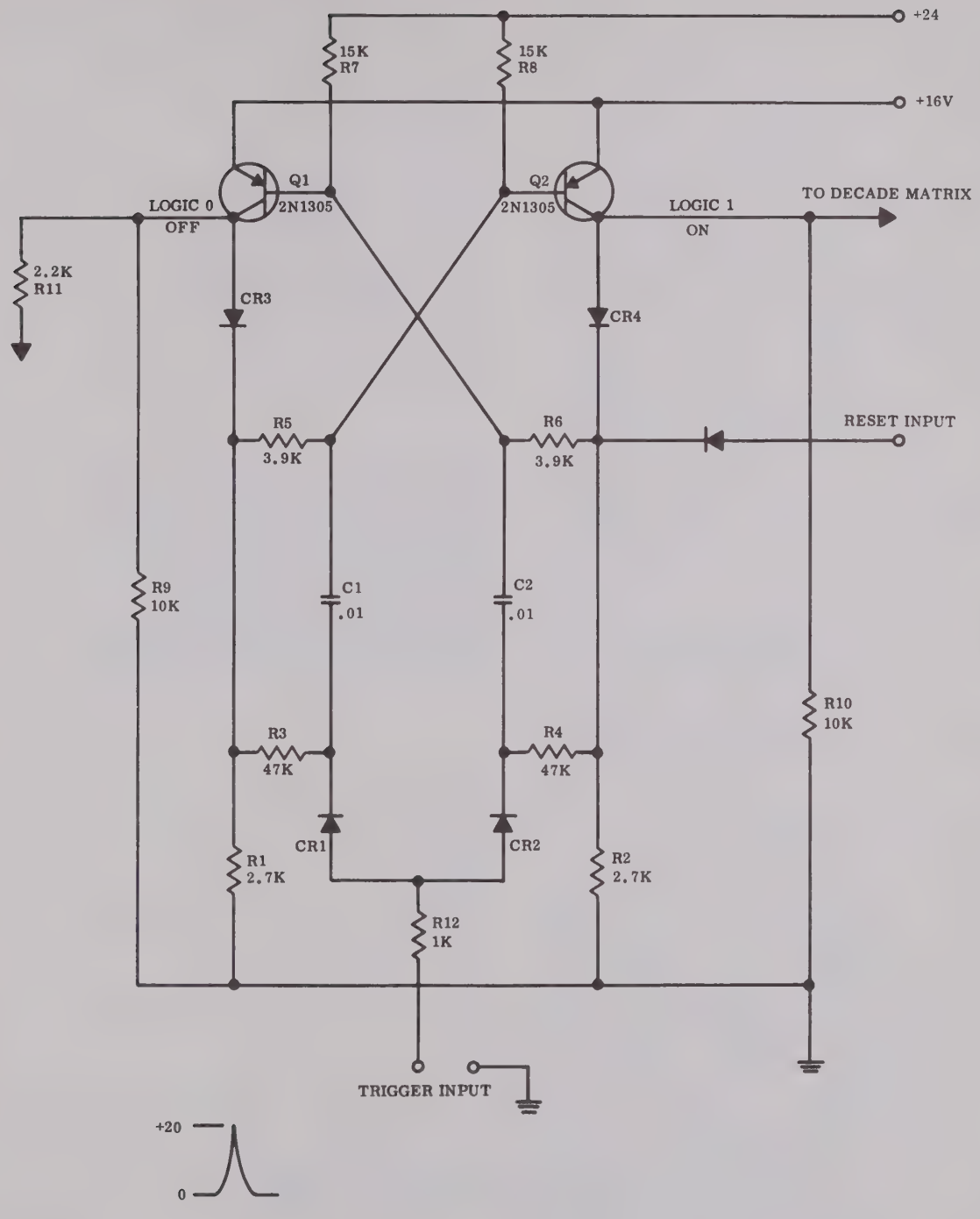
Relay contacts are shown in their de-energized positions. It can be seen that down-pulses are routed through four form C contacts and up-pulses through only two. Four form C contacts in the down line are required so that no matter which of the four relays are pulled in, the counter can be reset by a following down-pulse. This also disconnects the down-pulses from the down-pulse out line so that this decade must reset before down-pulses can be transferred to the next decade. From the truth table of figure 3-12 it can be seen that the 1 and 2* relays are both pulled in only at the count of 9. At all other counts only one of them is energized. Therefore, only two form C contacts are required to connect the up-pulses to the counter input or transfer the pulses to the next decade. This logic is simple, straightforward and demonstrates the enormous utility of the printact printed circuit relays.

By following the truth table of figure 3-12 one can determine the logic contact configurations for any of the 0 through 9 counts. A logic 1 indicates that a relay is energized (see position of dotted lines in figure 3-14).

A typical flip-flop circuit used in the decade counter (also in the range counter and polarity flip-flop) is shown in figure 3-15.

The reference designations in this figure are not related to those in schematic no. 50-114, Decade Assembly.

CR1, R3, C1 and CR2, R4, C2 are the input steering networks to the flip-flop. The positive going trigger is steered so as to



5015-12

Figure 3-15. Typical Flip - Flop Circuit Simplified Schematic Diagram

turn an on transistor off. Diodes CR3 and CR4 serve to isolate external loads from the biasing networks of the flip-flop. R9 and R10 provide a ground return for an off transistor. R11 is a base current limiting resistor for a relay buffer. R12 is a trigger current limiting resistor.

Refer to schematic 50-114 which shows the flip-flop circuits CR3, CR7, CR11, and CR14 are reset diodes connected to the down-pulse line. Diodes CR4 and CR8 are pulse (or level shift) feedback diodes used to set the 2nd and 3rd flip-flops whenever the 4th is set. See truth table of figure 3-12 Diodes CR32, CR33, CR34 and CR35 are part of the up-ranging logic of the DVM. The input to these diodes, called the range logic set, is used to set the 5th decade to a numerical 1 configuration when the up-range transfer from 9.9999V to 10.000V is being made. This causes the up-range transfer to occur with only 1 up and 4 down-pulses.

RELAY BUFFER

A relay buffer is used to energize the Printact logic relays in order to prevent excessive loading of the flip-flop. The relay coils require 40 ma at 12 V DC. The typical circuit shown in figure 3-16 operates between the +24 and +12 V power supply busses. The input signal is a +16 V level shift obtained from an on collector of a counter flip-flop.

With 0-volts input the base emitter junction is backed biased with +12 V and the relay K1 is de-energized. A +16 V input saturator Q1 and energizer relay K1, general purpose diode CR1 and Zener diode CR2 comprise a "quick dropout" circuit for the relay buffer. CR1 blocks the +24 volt supply to prevent relay K1 from being shunted by forward conduction through Zener diode CR2. When a relay is de-energized, the inductive "kick" of the relay coil is permitted to rise to the breakdown level of the Zener diode, 12 V, before conduction and clipping occurs. If CR2 were removed and CR1 used above, the dropout time would increase by a factor of up to 3 to 1. The Zener diode may be shared by the remaining buffers in the decade as shown in schematic 50-114.

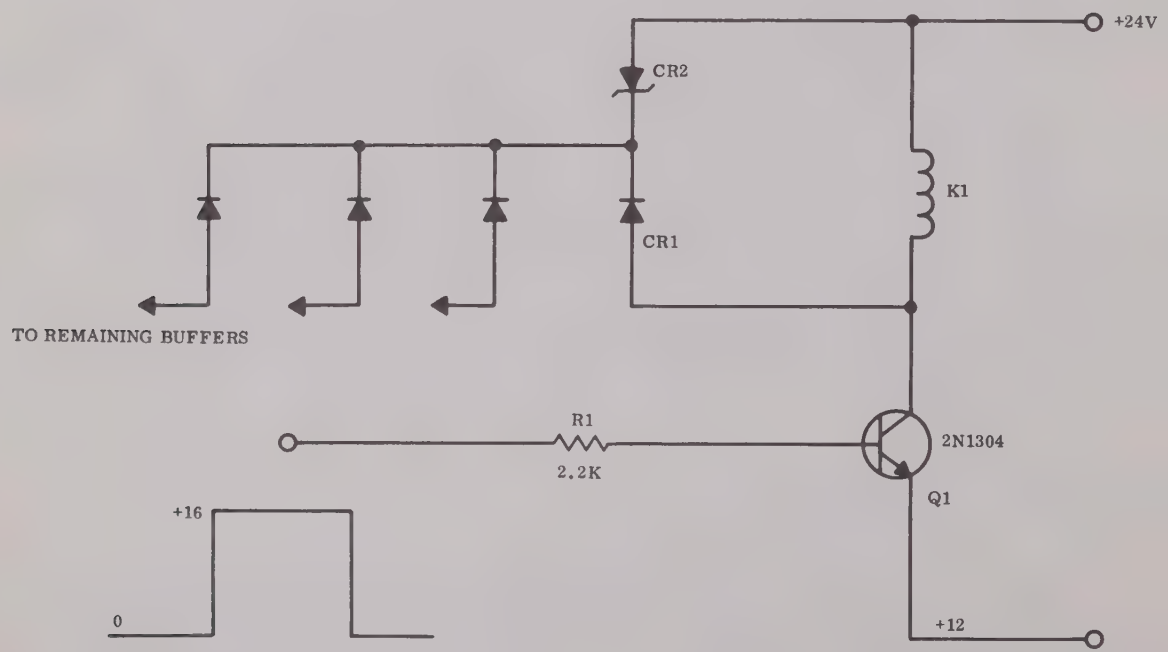


Figure 3-16. Relay Buffer Simplified Schematic Diagram

5015-13

POWER SUPPLY ASSEMBLY

The power supply assembly provides three regulated output voltages:

1. +12 VDC
2. +16 VDC and
3. +24 VDC.

The +24 VDC is utilized in the pulse amplifier of the amplifier assembly, as a biasing supply in all flip-flops, and as a collector supply for the chopper drive multivibrator and delay No. 1 in the logic assembly. The +16 VDC is used as a collector supply for all flip-flops. The +12 VDC is used to power chopper coil buffers, delay circuit No. 2 (see block diagram) and all lamp and range relay buffers. Relay buffers in the decades operate between the voltage levels of +12 VDC and +24 VDC.

Two 19 VAC windings supply power to the assembly. The assembly consists basically of two 12 V regulated supplies whose outputs are grounded and connected in such a way as to obtain +12 VDC and +24 VDC. The +16 VDC is obtained by means of an emitter follower regulator connected between the +12 and +24 volt outputs. A simplified block diagram of the circuitry is shown in figure 3-17

The assembly consists basically of two full-wave bridge rectifiers followed by a filter capacitor, two series regulators and one emitter follower regulator. A single-reference supply is shared as a reference source by both series regulators. This is made possible by using the output of one regulator as a reference for the other.

PRINT OPERATION

The standard 5015 DVM does not include a print-out function, however many users of the instrument desire this capability. The following paragraphs provide information on print operation for instruments containing this function.

Turn voltmeter function switch to ON and determine that the DVM is functioning properly by exercising it with suitable inputs over the range of 0 - ±10v dc.

Place function switch in CONTINUOUS position. This puts the voltmeter in a standby condition until a command to read voltage and print is received. This command may be called the "Read Command."

The "Read Command" is given by Form C contacts connected to Pins 76, 79, and 80 of Print Connector J9 as shown on Schematic 50-67. These contacts are supplied by the customer. The normally closed contacts connected to pin 79 must be opened and closed to provide a "Read Command." The subsequent closure initiates the "Read Command."

This contact closure triggers the print delay circuit causing relays K1, K3, and K4, to pull in. The opening of relay K4 contacts releases the voltmeter from the standby condition. The closing of relay K1 contacts completes a circuit for up and down pulses to be applied to the print delay circuit, thus, keeping relays K1, K3, and K4 held in as long as the voltmeter is balancing.

When relay K3 drops out, approximately 100 millisecond after the last up or down pulse occurs, both the amplifier inhibit multi and the print command delay multi are triggered. The normally open contacts of Relay K2 close for 15 milliseconds after relay K3 drops out to provide a contact closure "Print Command" available at pin 49 and pin 37 of print connector J9. The dropout of relay K4, simultaneously with relay K3, puts the voltmeter back in the standby condition while the external print cycle proceeds to record the binary coded decimal voltage levels which are available at print connector J9.

The operation of the amplifier inhibit multi, and relay K5 are redundant in the CONTINUOUS print mode. In the AUTO

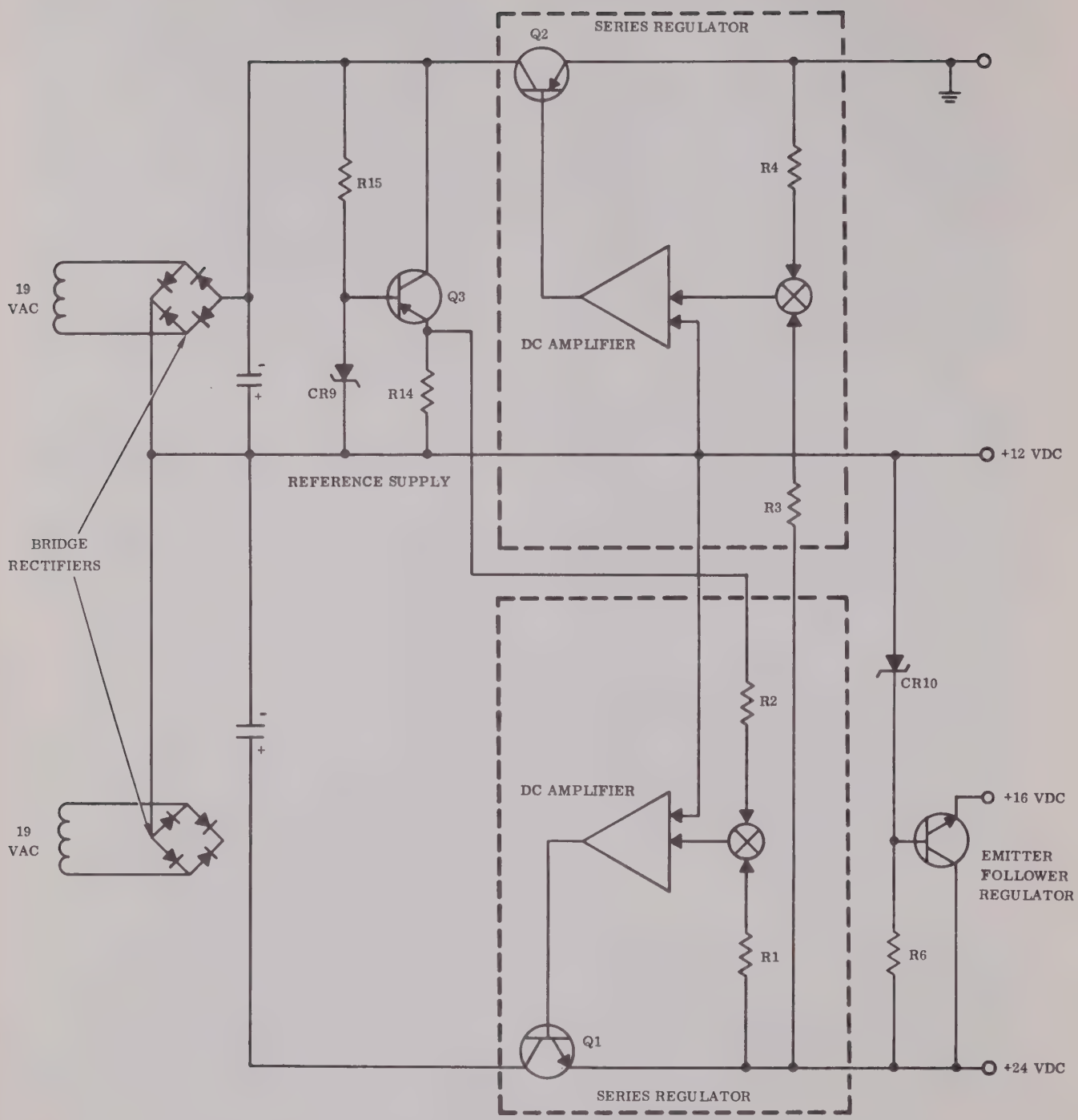


Figure 3-17. Power Supply Simplified Block Diagram

5015-14

mode, this circuit places the voltmeter in STANDBY for 250 millisecond after relay K4 drops out.

In the AUTO mode of print, the voltmeter is continuously enabled to read voltage and voltage changes. When voltage is first applied to the voltmeter, up and down pulses which occur while the instrument balances are applied to the print delay circuit through contacts of the function switch. Relays K1, K3, and K4 pull in; however, the contact closure of relay K1 is redundant, relay K4 contacts have been disabled by the function switch, and relay K3 contacts close to ground. One hundred milliseconds after the last up or down pulse (signifying balance has occurred) relays K1, K3, and K4 drop out. The dropout of relay K3 triggers amplifier inhibit multi and energizes relay K5 for 250 milliseconds. The contacts of relay K5 place the voltmeter in STANDBY. The print command multi is triggered simultaneously with the amplifier inhibit multi. The normally open contacts of relay K2 close for 15 milliseconds to provide a contact closure "Print Command."

After 250 milliseconds, relay K5 drops out, remove the voltmeter from the STANDBY condition, and thus puts the instrument in readiness to read and print the next change in voltage.

The contacts of relay K2 can be arranged (on special request) to provide normally closed contacts, rather than normally open, available at pins 49, and 37 of J9. It is recommended that the trailing edge of the 15 millisecond closure period, i.e., when the contacts of relay K2 open again, be used to initiate "Print Command" to external print equipment. This times the "Print Command" to occur 15 milliseconds after the voltmeter has been placed in the STANDBY condition by relay K5.

CHAPTER IV

CALIBRATION

When the Model 5015 Digital Voltmeter is not making readings within specifications, it is time for calibration, repair or both. In the calibration information provided in this chapter, it is assumed that the instrument is in good working order and only requires calibration. If any components are defective, it may be difficult, if not impossible, to calibrate the instrument properly.

The calibration procedure is divided into four distinct areas: gain adjustment, basic accuracy adjustment, range adjustment, and final gain check. See figure 4-1 to determine the locations of all adjustment points and see figures 4-2 and 4-3 for test equipment connections.

EQUIPMENT REQUIRED

1. A bank of nine standard cells: NLS E.M.F. Standard No. 3006.

2. A DC High Voltage Supply and Calibrator, NLS Model 3021.

3. A Ratio Test Fixture, NLS Model 3022.

4. A Dekavider, Model DV-411, Electro Scientific Industries.

5. A DVM Signal Input Cable, No. 5123.

6. An Interconnecting Cable, DC High Voltage Supply and Calibrator, No. 3022-008.

7. An Interconnecting Cable, Ratio Test Fixture to DV-411 Dekavider, No. 3022-033.

8. A DVM External Reference Cable, No. 5124.

INITIAL PREPARATION

1. Plug DVM power cord into 115-volt line. Turn power switch to STANDBY. Turn FUNCTION switch to VOLTS. Allow meter to warm up for one-half hour.

2. Interconnect the Ratio Test Fixture, DC High Voltage Supply and Calibrator and DV-411 Dekavider using Cables 3022-008 and 3022-033.

3. Turn DC High Voltage Supply power switch to STANDBY and allow the unit to warm up for one-half hour.

4. Turn RATIO switch to OFF and Range switch to 10 on the Ratio Test Fixture. Connect DVM to Ratio Test Fixture as shown in figure 4-2.

GAIN ADJUSTMENT

1. Turn DVM power switch to ON. Turn DC High Voltage Supply and Calibrator power switch to ON.

2. Set all Dekavider dials to zero. All DVM readout windows should read zero.

3. Using the least significant dial of the Dekavider, increase the signal voltage to the voltmeter and then slowly decrease it.

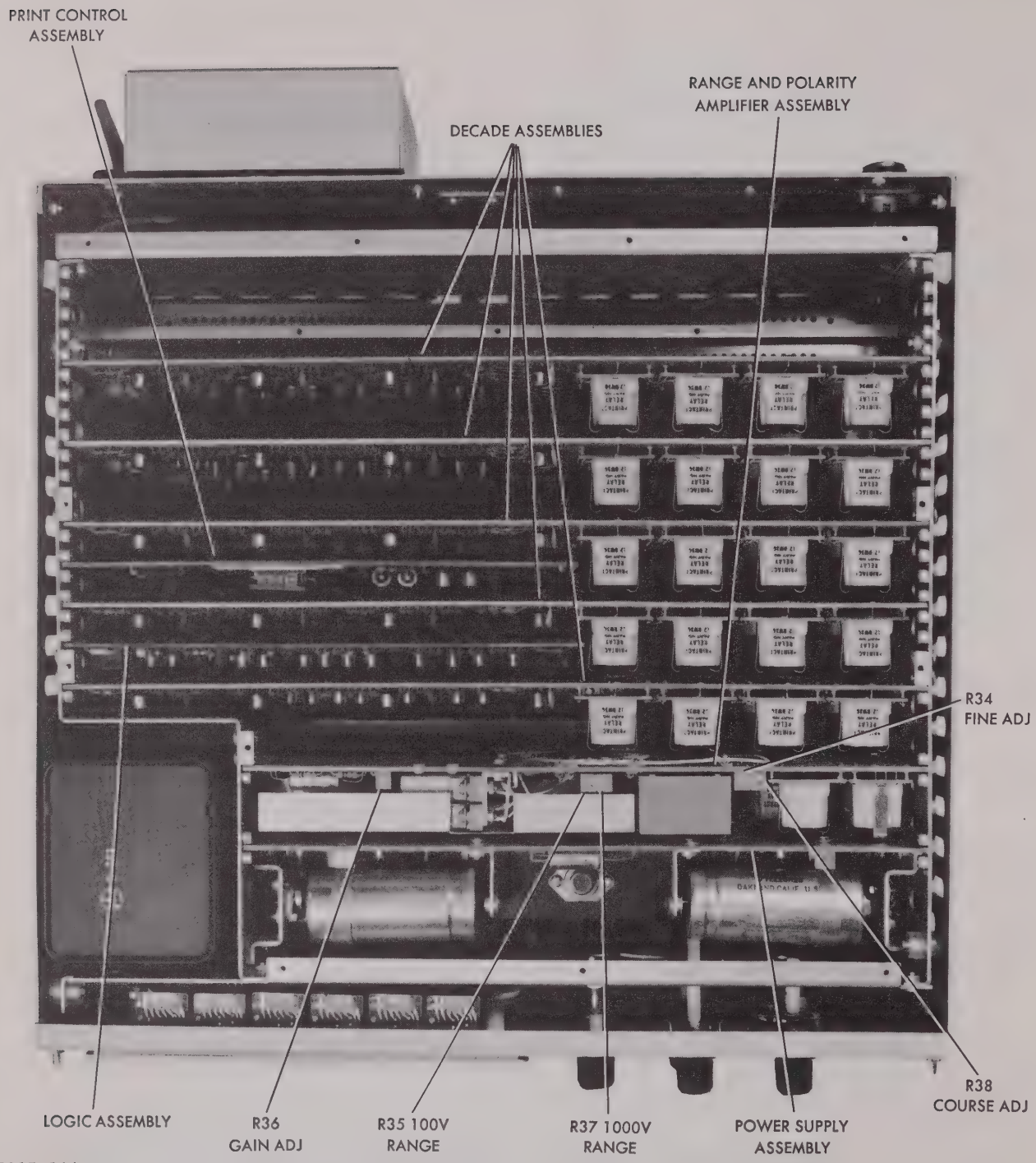


Figure 4-1. Location of adjustment Points

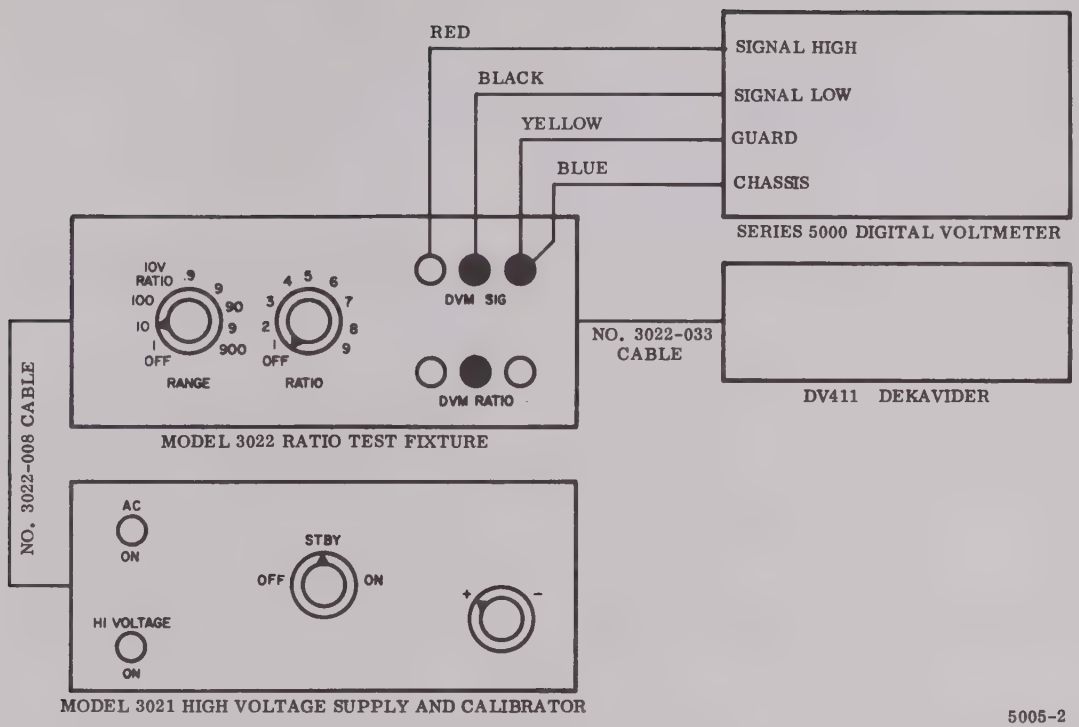


Figure 4-2. Cable Connections

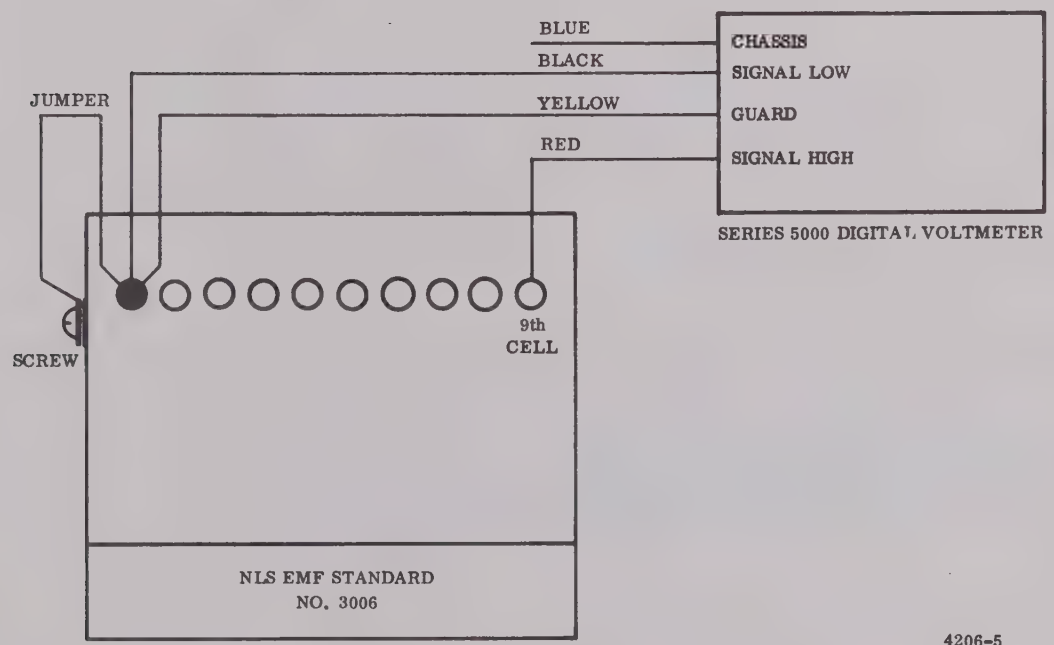


Figure 4-3. Cable Connections

The DVM should count down one digit at a time. If not, error amplifier gain is too low.

Remove the top cover and top of guard box. Some instruments will have access holes for potentiometer adjustments in the guard box top cover. If not, always replace guard box cover (use only one screw) temporarily after making the adjustments. Increase gain by turning gain potentiometer R-36 on the Amplifier Assembly in a clockwise direction. Slowly decrease signal input to the DVM. Gain is correct when the meter barely counts down 1 digit at a time. The instrument now has a 100 microvolt sensitivity. If gain is too high - least significant digit unstable or rolling - R36 should be turned counter-clockwise to reduce gain. Keep DVM front panel sensitivity control fully clockwise during this adjustment.

WARNING

Do not disconnect voltmeter input leads from DC source when measuring voltages in the 100V to 1000V range. The filter capacitors will remain charged to these dangerous levels for considerable lengths of time if the input is opened. The Digital Voltmeter should be ranged down to the basic range after measuring high voltages before being disconnected from the source.

BASIC ACCURACY CALIBRATION

1. Disconnect DVM signal input leads from Ratio Test Fixture, and connect to standard cell bank as shown in figure 4-3.

2. The DVM should display the carded value of the 9 standard cells, e.g. 9.1651V; if not, adjust coarse and fine adjustment potentiometers R-38 and R-34 until it does. The calibration is now set in the basic range of 10 VDC.

RANGE CALIBRATION

Reconnect DVM as in Figure 4-2.

1. Set RANGE switch on the Ratio Test Fixture to 9. Observe the reading on the 9.9999 V range and record. Say it was 9.1364.

2. Next, set RANGE switch to 90. Observe the reading. Meter should read 91.364. If not, adjust R-37 until it does.

3. Next, set RANGE switch to 900. Observe the reading. Meter should read 913.64. If not, adjust R-35 until it does.

FINAL GAIN CHECK

Re-connect the DVM to Ratio Test Fixture as before (Figure 4-2). Set all Dekavider dials to zero. Apply input signals to the DVM using the least significant dial as the Dekavider. Check gain as before, Step 3 under GAIN ADJUSTMENT. Adjust gain to make meter count down one digit at a time. Use only as much gain as needed to barely get one-digit steps as meter counts down.

RATIO CHECK

Turn DVM FUNCTION switch to RATIO. Connect external reference leads to NLS Model 3022 Ratio Test Fixture. Turn RANGE switch to 10 V RATIO and RATIO switch to 1 through 9. DVM reading should agree with carded values.

CHAPTER V

MAINTENANCE

If the Digital Voltmeter is not working properly, or if it cannot be calibrated according to instructions, service will be required.

Before seeking out specific defective components, it is best to establish that the several power supplies are working. Specifically, voltage checks should be made at the voltage output points of the power supplies as indicated on the schematic drawings. A simple 20,000 ohm-per-volt d'Arsonval type meter may be used for these measurements. The voltage measurements should indicate correct values ±15% when read on a voltmeter with a rated accuracy of ±13%. The outputs of the regulated power supplies cannot be accurately read by this method, but in practice the accuracy of their outputs need not be known; if a regulated power supply fails, it is most likely that the voltage error will be gross (or there will be no output at all) and therefore detectable with simple measuring instruments.

If a measured voltage appears to be at an improper value, the associated power supply components should be checked: if none of these are found to be defective, it will be necessary to proceed along the defective power path, checking wiring, connectors, printed circuitry, and finally components on the boards. An obvious way to make a speedy check is to replace suspected defective boards with known good ones. Since the decade boards are all interchangeable (except as noted on page 1-1), a malfunction affecting one decade of the readout can be made to affect other decades. For this reason, it is suggested that a trial and error approach be used and the decade boards be interchanged. If the malfunction then manifests itself in a previously unaffected decade, the defective board can be readily isolated. From this point on, a test of components will locate the precise area of failure.

It is suggested that the individual schematics be studied so as to better know what outputs may be expected at each function.

RELAY HANDLING

Tests by NLS, several other companies and the relay manufacturer have shown that the printed circuit relays used in the 5000 Series instruments are very reliable units. For example, in the NLS life tests, the relays were operated for the equivalent of 20 years of DVM use at 2 seconds per reading, 8 hours a day, 7 days a week, and there were no failures.

To obtain the fullest measure of this reliability, the instructions below should be followed.

1. Do not attempt to adjust relay contacts. The relays are adjusted for correct contact preload at the manufacturer.

2. Do not trade contact assemblies from relay to relay. The manufacturer's contact pre-load adjustment takes into account manufacturing tolerances of the entire relay assembly.

3. Do not manipulate the contact assembly by hand. This may bend contacts and change the preload setting.

4. Retain the plastic cover on the bottom of the relay until it is installed on a decade board.

5. Remove rosin and degrease the relay contact printed circuit board before final installation of the relays. For removing contamination of organic origin, FREON is recommended. If means are taken to protect the plated printed circuit wires on the relay contact printed circuit board, rosin may be removed from the solder connections by blasting.

6. Do not handle the moving armature blades. This avoids contamination or bending blades out of adjustment.

7. Do not operate relay when not mounted on the printed circuit contact board. Back pressure on blades is required to start armature back into the magnetic field.

8. Contacts on relay and board can be cleaned by buzzing relay with AC current at rated voltage when mounted on the circuit board. This also assures proper seating of any armature dislodged in shipment.

9. Do not hand-adjust relay blades. The relays have been factory adjusted for the required overtravel and wiping action. If the relay does not operate for any reason, replace it with another relay.

Table 5-1 lists specific types of malfunction. Note that any of dozens of components could fail and yet the symptom would be the same for all, there is no one compo-

SYMPTOM	PROBABLE DEFECTIVE BOARD
Readout locks on 9 in a given decade	Decade Ass'y (Relays)
Polarity lights are out or are incorrect.	Logic Ass'y, Readout
Decimal lights are out or are incorrect.	Logic Ass'y, Readout
Multiple lights appear in one or more decades.	Decade Ass'y
A particular digit fails to illuminate.	Readout Bulb
Readout is locked at 9999, or is unstable and seeks 9999 regardless of input voltage.	Amplifier Ass'y Logic Ass'y
Readout displays 9999 in one polarity, but not in other, regardless of input voltage.	Logic Ass'y Amplifier Ass'y
Instrument skips digits, or has "holes" in decades. Transfers and linearity are poor.	Decade Ass'y (Bridge Resistors)
Readout shows only certain numbers in decades.	Decade Ass'y (Decode Matrix)

Table 5-1. Troubleshooting

nent which can readily be singled out as a consistent offender. For this reason, the most useful approach to trouble-shooting is to provide a list of possible types of failure and identify the plug-in board or circuit area most likely to contain the defective component.

SYMPTOM	PROBABLE DEFECTIVE BOARD
Instrument reads correctly in one polarity, but loses digits in the other.	Amplifier Ass'y (Reference, Polarity Relays, Circuit board Leakage)
Readout illumination is dim.	Power Supply Ass'y
Readout displays erroneous values which are somewhat proportional to the input voltage.	Amplifier Ass'y, (Range Divider)
Readout Display is consistently higher than the input voltage.	Amplifier Ass'y, (Reference)
Readout "sticks" on particular numbers.	Decade Ass'y (Relays)

Table 5-1. Troubleshooting (Continued)

DIGITAL READOUT MAINTENANCE

The digital readout assembly (Figure 5-1) does not ordinarily require maintenance other than lamp bulb replacement and an occasional cleaning. Most readouts have decals on the readout cover, on the top and bottom of each readout, to show which contact is providing the signal for each digit or symbol. If decals are not provided, see figure 5-2 for information to locate each digit or symbol contact point.

Lamp Bulb Replacement

When it is determined that a digit or symbol is not illuminating within a specific readout display, the lamp bulb may be replaced by performing the following steps:

1. Remove the four Allen-head screws attaching the bezel to the DVM chassis. The readout assembly may now be withdrawn from the instrument.

2. Locate the correct contact point for the defective bulb either by noting the decal on the specific readout or by referring to figure 5-2.

3. Remove the lamp board assembly (top or bottom) from the readout containing the defective bulb by removing the two attaching screws.

4. Gently withdraw the lamp board assembly away from the lamp block within the readout cover.

5. Unsolder defective lamp bulb and replace it with a functioning T-1 3/4 14-volt lamp bulb.

6. Re-assemble readout assembly in

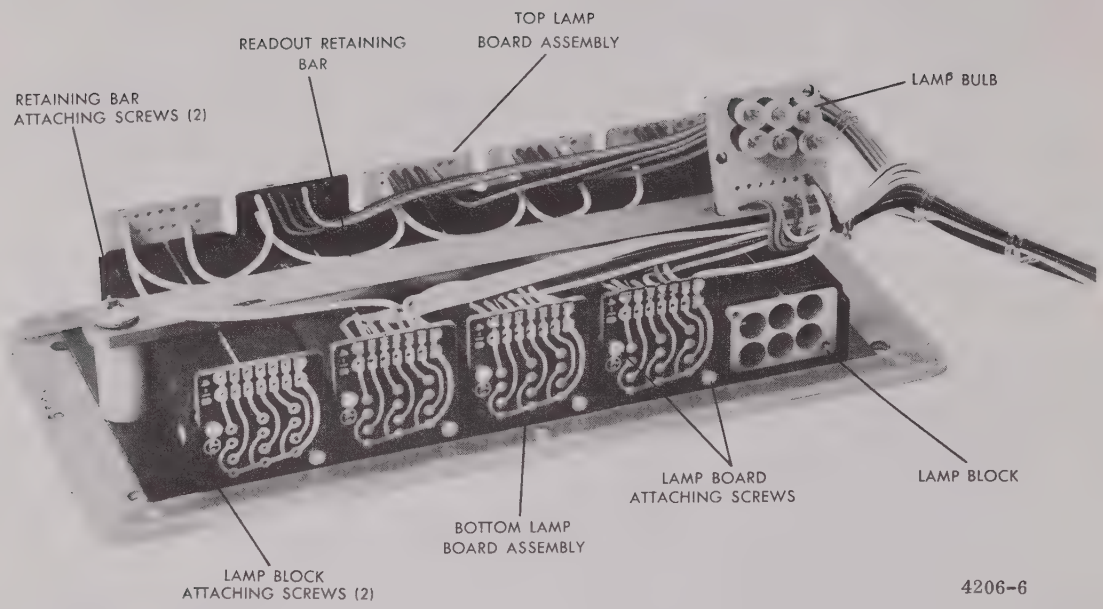


Figure 5-1. Readout Assembly

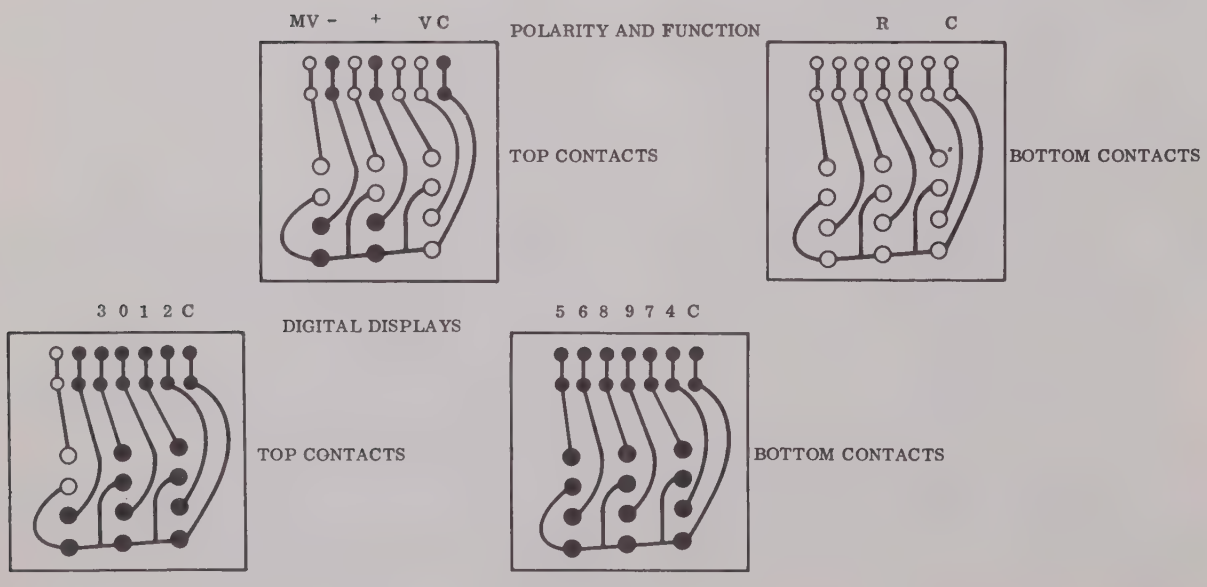


Figure 5-2. Lamp Bulb Replacement

reverse order of disassembly.

Readout Window Cleaning

Under extremely adverse dust or humidity conditions, the individual readout windows may require cleaning. If accumulated dust particles are likely to be unusually abrasive, a camel-hair brush or artist's sable brush should first be used to remove loose dust particles. The windows may then be cleaned with commercial isopropyl alcohol and lint-free paper, such as Kimwipes 900-L, manufactured by Kimberly-Clark, Neenah, Wisconsin. The windows may also be cleaned if they are dipped in alcohol and then blown dry with compressed air.

To remove the windows from the readout, perform the following steps:

1. Perform Step No. 1 under Lamp Bulb Replacement.

2. Remove readout retaining bar by removing two attaching screws.

3. Perform Step No.'s 3 and 4 (both top and bottom lamp boards) under Lamp Bulb Replacement for each readout to be cleaned.

4. Remove each two sets of lamp block attaching screws.

5. Gently press against one lamp block until the other lamp block may be removed and until windows can be withdrawn with finger-tip pressure.

6. Clean the windows as set forth above.

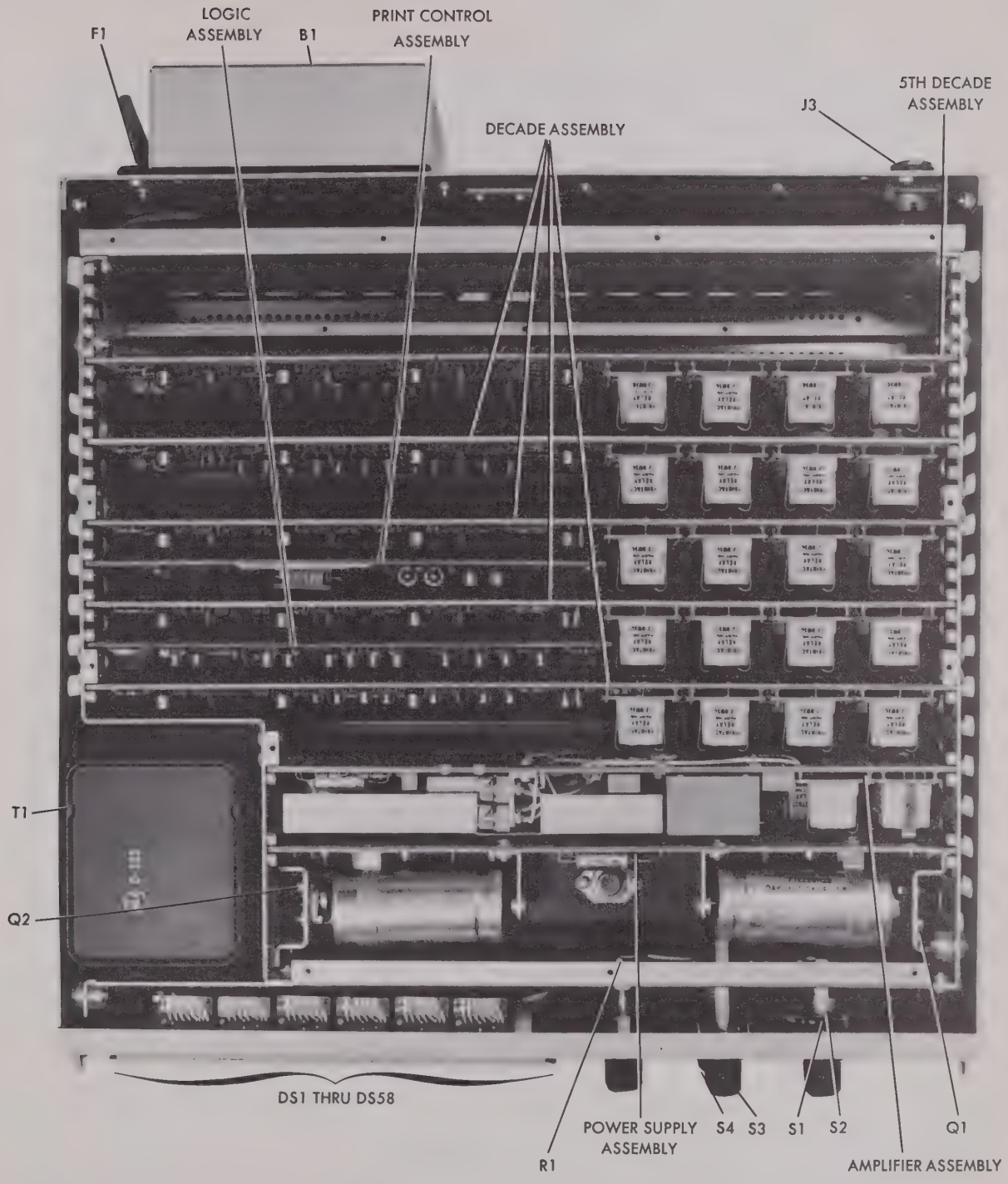
NOTE

It is well to be systematic about this operation so as to avoid replacing the windows in improper order. Care should be taken to avoid replacing the windows backwards; this type of error is most likely to occur with windows marked 1, 0, 6, 8, 9, -, or +. Note that the engraved side always faces to the rear of the readout.

7. Stack the windows in proper order and press them together with mild finger-tip pressure. Avoid fingerprints on the windows. After ensuring that the numerals are right side up and that the engraved side faces the rear of the readout, gently slip the windows into the cover.

8. Re-assemble readout and readout assembly in reverse order of disassembly.

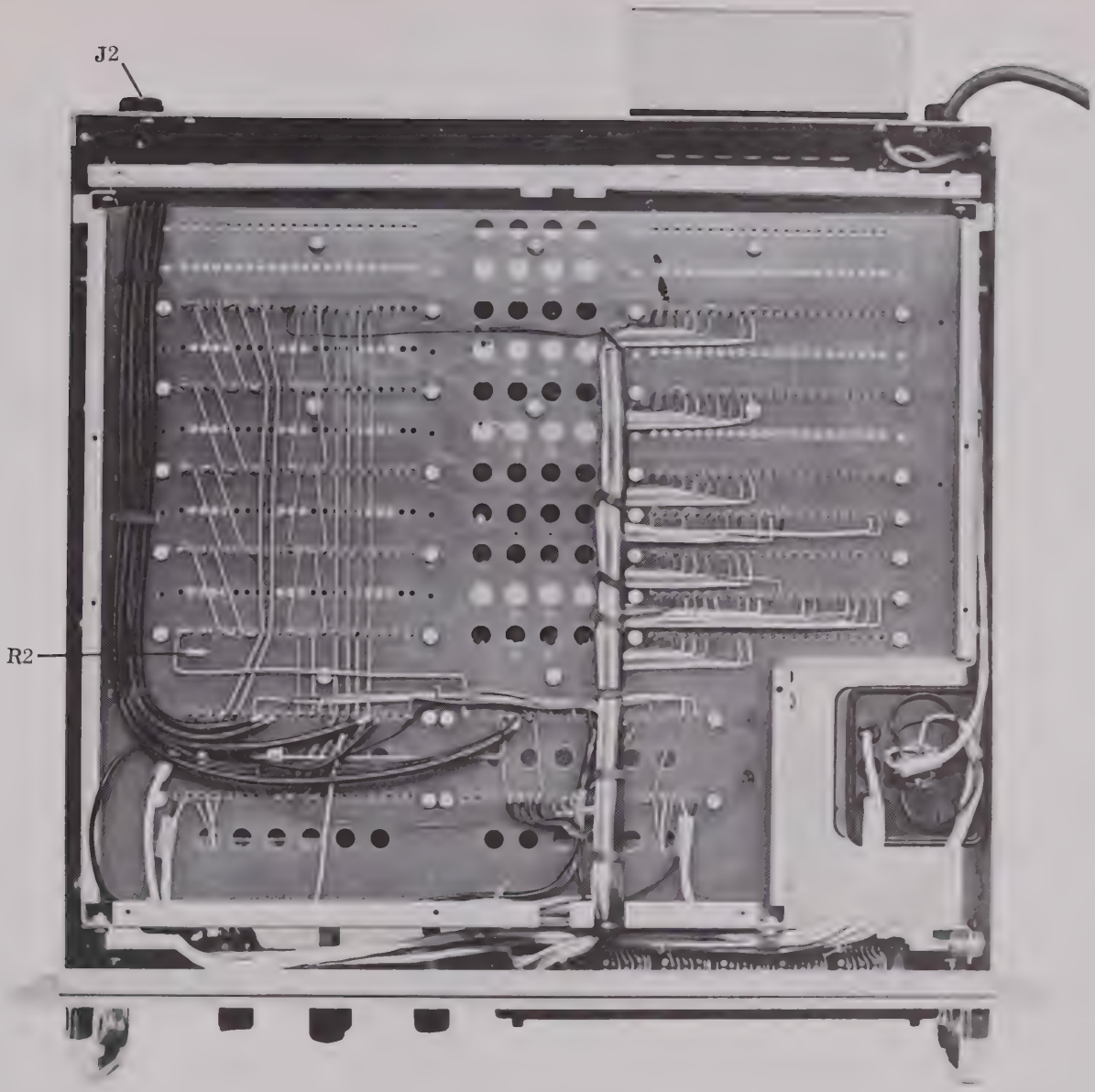
If the readout contains a Polaroid filter in front of the display, it may be removed and cleaned in the same manner as the readout windows. Care should be taken to reinstall the filter so that the polarized action is correct. Look through the filter at a piece of shiny metal, such as the chrome rim of a wrist-watch. If the metal shows a markedly violet cast, then the filter front is the surface closest to the eye.


F1
LOGIC ASSEMBLY
B1
PRINT CONTROL ASSEMBLY
DECADE ASSEMBLY
J3
5TH DECADE ASSEMBLY
T1
Q2
DS1 THRU DS58
R1
POWER SUPPLY ASSEMBLY
S4
S3
S1
S2
Q1
AMPLIFIER ASSEMBLY

5015-3A

Digital Voltmeter

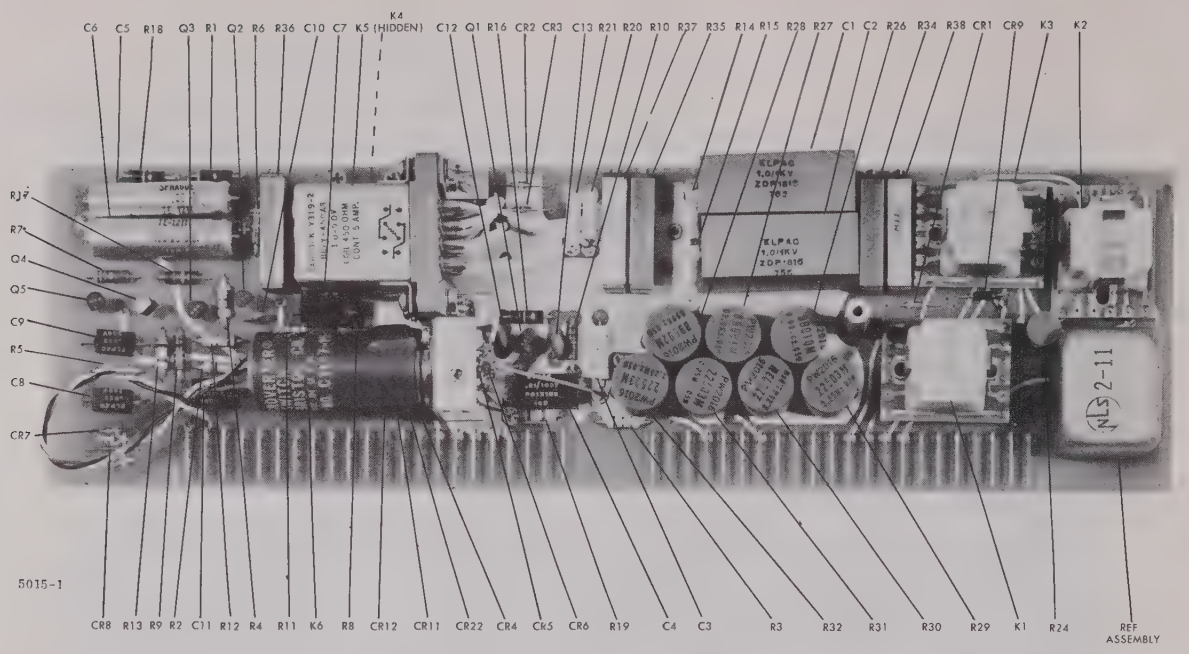
CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
F1	303001	Fuse	1	Littlefuse
J3	97-3102A-14S-5P-426	Connector	1	Amphenol
Q1	2N3232	Transistor	1	
Q2	2N1540	Transistor	1	
R1	50-09	Potentiometer		NLS
S1	T-106	Switch, Wafer	1	NLS
S2	50-60	Switch, Power	1	NLS
S3 and S4	5084	Switch Assembly	1	NLS
T1	3-7	Transformer	1	NLS
	5123	Cable Assembly	1	NLS
	5124	Cable Assembly	1	NLS
DS1 thru DS58	4-19-1	Lamp Bulb	58	NLS
B1	WS2170F	Fan, Boxer	1	
	50-7	Power Supply Assembly	1	NLS
	50-61	Decade Assembly	4	NLS
	50-67	Print Control Assembly (Optional)	1	NLS
	50-114	5th Decade Assembly	1	NLS
	50-177	Amplifier Assembly	1	NLS
	50-192	Logic Assembly	1	NLS



5015-2

Digital Voltmeter

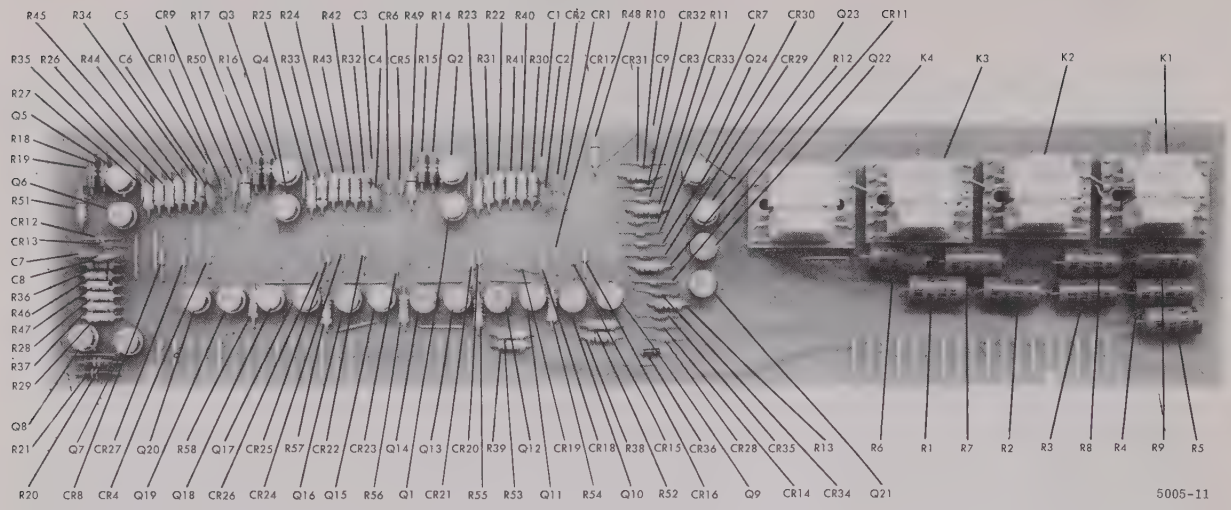
CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
J2	97-3102A-14S-2P-416	Connector	1	Amphenol
R2	GP$\frac{1}{2}$	Resistor, 100K, $\frac{1}{2}$W, 1%	1	Texas Inst.



Amplifier Assembly, 50-177

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1 and C2	2DP1816	Capacitor, 1 MFD, 1000V	2	Elpac, Inc.
C3	PD1A102K	Capacitor, 0.001 MFD, 100V	1	Elpac, Inc.
C4	PD1X103	Capacitor, 0.001 MFD, 100V	1	Elpac, Inc.
C5 and C6	TE1211	Capacitor, 100 MFD, 25V	2	Sprague Prod
C7	VX1X254K	Capacitor, 0.25 MFD, 100V	1	Elpac, Inc.
C8 and C9	2XX3242	Capacitor, 0.022 MFD, 200V	2	Elpac, Inc.
C10	DD250	Capacitor, 25 PPF, 1000V	1	Centralab
C11	VX1X03J	Capacitor, 0.1 MFD, 100V	1	Elpac, Inc.
C12 and C13	RMC1500	Capacitor, 50PPF, 1000V	2	Radio Mat
CR1 thru CR4, CR7, CR8, CR10, CR11 and CR12				
CR5 and CR6	1N625	Diode	2	
CR9	1N963B	Diode, Zener	1	Motorola
K1 thru K3	12BW3G	Relay, Printact	3	Executone
K4 and K5	BR74-450A8	Relay, Printact	2	
K6	CH1417-27	Chopper		The Bristol
Q1 thru Q5	T1418	Transistor		Texas Inst
R1	GP$\frac{1}{2}$	Resistor, 30 ohms, $\frac{1}{2}$W, 1%	1	Texas Inst

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R2	GP½	Resistor, 36 ohms, ½W, 1%	1	Texas Inst
R3	GP½	Resistor, 180 ohms, ½W, 1%	1	Texas Inst
R4	GP½	Resistor, 270 ohms, ½W, 1%	1	Texas Inst
R5	GP½	Resistor, 330 ohms, ½W, 1%	1	Texas Inst
R6 and R7	GP½	Resistor, 360 ohms, ½W, 1%	2	Texas Inst
R8	GP½	Resistor, 430 ohms, ½W, 1%	1	Texas Inst
R9 and R10	GP½	Resistor, 1K, ½W, 1%	2	Texas Inst
R11	GP½	Resistor, 1.2K, ½W, 1%	1	Texas Inst
R12	GP½	Resistor, 6.8K, ½W, 1%	1	Texas Inst
R13 thru R15 & R19	GP½	Resistor, 10K, ½W, 1%	4	Texas Inst
R16 and R17	GP½	Resistor, 12K, ½W, 1%	2	Texas Inst
R18	GP½	Resistor, 20K, ½W, 1%	1	Texas Inst
R20 and R21	GP½	Resistor, 910K, ½W, 1%	2	Texas Inst
R24	PW1220	Resistor, Value is factory selected for each instrument	1	NLS
R26	PW2016	Resistor, 9.991K, 0.05%	1	NLS
R27	PW2016	Resistor, 89.9K, 0.05%	1	NLS
R28	PW2016	Resistor, 899K, 0.05%	1	NLS
R29 thru R32	PW2016	Resistor, 2.25 Megohm, 0.5%	4	NLS
R34	275-1-101	Potentiometer, 100 ohms (Wire Wound)	1	Bourns
R35 and R36	275-201	Potentiometer, 200 ohms (Wire Wound)	2	Bourns
R37	275-1-202	Potentiometer, 2K (Wire Wound)	1	Bourns
R38	275-1-502	Potentiometer, 20K (Wire Wound)	1	Bourns



1st thru 4th Decade Assembly, 50-61

5th Decade Assembly, 50-114

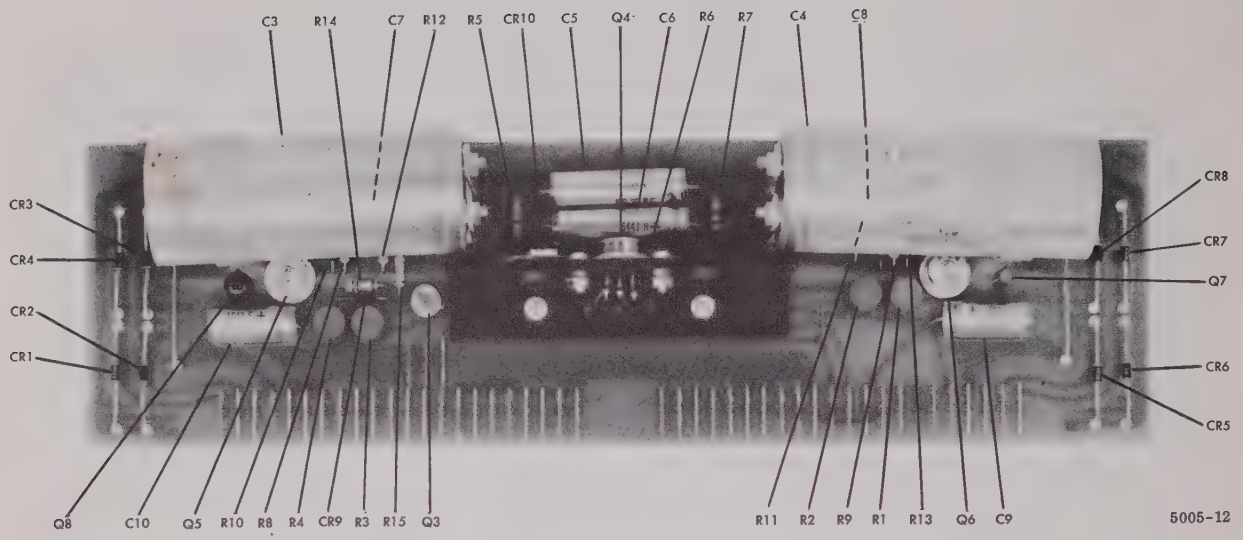
CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1 thru C9	DDM-103	CAPACITOR, 0.01 MFD, 140V	9	Centrlab
CR1 thru CR35	5003-002	DIODE	35	NLS
CR36	1N963B	DIODE, ZENER	1	Motorola
K1 thru K4	12BW3G	RELAY, PRINTAGE	4	Executone, Inc.
Q1 thru Q20	2M1305	TRANSISTOR	20	Texas Instruments
Q21 thru Q24	2N1304	TRANSISTOR	4	Texas Instruments
R1 & R6	AW1224	RESISTOR, 10K, 1/2W, 0.01%*	2	NLS
R2,. R4, R7 & R9	AW1224	RESISTOR, 20K, 1/2W, 0.01%*	4	NLS
R3 & R8	AW1224	RESISTOR, 40K, 1/2W, 0.01%*	2	
R5	AW1224	RESISTOR, 11.111K, 1/2W, 0.05%	1	
R10 thru R13	Com'l	RESISTOR, 2.2K, 1/2W, 10% (Carbon)	4	

*NOTE: On the 5th Decade Assembly, Part No. 50-114, Accuracy is ±0.005%, matched to 0.0025%. Temperature Coefficient 0-50 PPM, all in the same direction.

1st thru 4th Decade Assembly, 50-61

5th Decade Assembly, 50-114

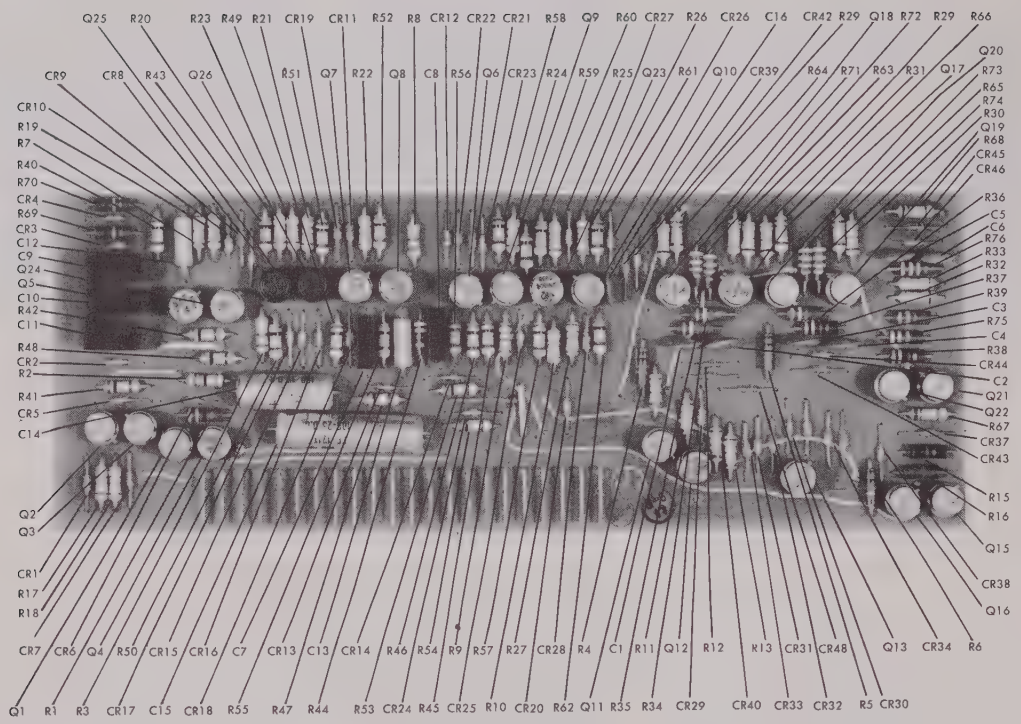
CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R14 thru R21	Com'l	RESISTOR, 15K, 1/2W, 5% (Carbon)	8	
R22 thru R29	Com'l	RESISTOR, 3.9K, 1/2W, 5% (Carbon)	8	
R30 thru R37	Com'l	RESISTOR, 47K, 1/2W, 5% (Carbon)	8	
R38 & R39	Com'l	RESISTOR, 10K, 1/2W, 5% (Carbon)	2	
R40 thru R47	Com'l	RESISTOR, 2.7K, 1/2W, 5% (Carbon)	8	
R48 thru R51	Com'l	RESISTOR, 1K, 1/2W, 5% (Carbon)	4	
R52 thru R58	Com'l	RESISTOR, 5.6K, 1/2W, 5% (Carbon)	7	



CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1 thru C4	1B1645	CAPACITOR, 1000 MFD, 25V	4	Industrial Condenser
C5 & C6	TE1211	CAPACITOR, 100 MFD, 25V	2	Sprague Products
C7 & C8	BT005	CAPACITOR, 0.005 MFD, 100V	2	Radio Materials Co.
C9 & C10	TE1162	CAPACITOR, 100 MFD, 15V	2	Sprague Products
CR1 thru CR8	1N4005	DIODE	8	Motorola
CR9	1N758A	DIODE	1	Cont. Devices
CR10	1N3824	DIODE	1	Motorola
Q3	2N1305	TRANSISTOR	1	Texas Instruments
Q4 & Q6	2N1701	TRANSISTOR	2	RCA
Q5	2N1183	TRANSISTOR	1	RCA
Q7	2N3711	TRANSISTOR	1	Texas Instruments
Q8	2N3702	TRANSISTOR	1	Texas Instruments
R1 thru R4	PW1220	RESISTOR, 2.7K, 1/2W, 1%	4	NLS
R5 & R7	Com'l	RESISTOR, 390 ohms, 1/2W, 5% (Carbon)	2	
R6	Com'l	RESISTOR, 300 ohms, 1/2W, 5% (Carbon)	1	

Power Supply Assembly, 50-7

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
R8 thru R11	Com'l	RESISTOR, 1K, 1/2W, 5% (Carbon)	4	
R12 & R13	Com'l	RESISTOR, 10 ohms, 1/2W, 5% (Carbon)	2	
R14	Com'l	RESISTOR, 10K, 1/2W, 5% (Carbon)	1	
R15	Com'l	RESISTOR, 680 ohms, 1/2W, 5% (Carbon)	1	



5015-4

Logic Assembly, 50-192

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
C1 thru C6	PD1J103	Capacitor, 0.01 MFD, 100V	6	Elpac, Inc.
C7 and C8	ZX2X473K	Capacitor, 0.047 MFD, 200V	2	Elpac, Inc.
C9 thru C11	VX1X254K	Capacitor, 0.25 MFD, 200V	3	Elpac, Inc.
C12 and C13	CS13AF2R2M	Capacitor, 2.2 MFD, ±10%	2	
C14	TE1162	Capacitor, 100 MFD, 15V	1	Sprague Prod
C15	TE1211	Capacitor, 100 MFD, 25V	1	Sprague Prod
C16	DDM103	Capacitor, 0.01 MFD, 150V	1	Centralab

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
CR1 thru CR34, CR37 thru CR46 and CR48	5003-002	Diode	45	NLS
Q1 thru Q13 and Q15 thru Q22	2N1305	Transistor	21	Texas Inst
Q23	2N1304	Transistor	1	Texas Inst
Q24	2N697	Transistor	1	Texas Inst
Q25 and Q26	3N58	SCS	2	General Elect
R1	Com'l	Resistor, 47 ohms, ½W, 5%, (Carbon)	1	
R2	Com'l	Resistor, 56 ohms, ½W, 5%, (Carbon)	1	
R3	Com'l	Resistor, 470 ohms, ½W, 5%, (Carbon)	1	
R4 thru R6	Com'l	Resistor, 1K, ½W, 1%, (Carbon)	3	
R7	Com'l	Resistor, 1.2K, ½W, 1% (Carbon)*	1	
R8	Com'l	Resistor, 270 ohms, ½W, 5% (Carbon)	1	
R9 thru R13, R15 and R16	Com'l	Resistor, 1.5K, ½W, 5% (Carbon)	7	
R17 thru R27	Com'l	Resistor, 2.2K, ½W, 5% (Carbon)	11	
R28 thru R33	Com'l	Resistor, 2.7K, ½W, 5% (Carbon)	6	
R34 thru R39	Com'l	Resistor, 3.9K, ½W, 5% (Carbon)	6	
R40 and R41	Com'l	Resistor, 10K, ½W, 1% (Carbon)	2	
R42, R43 and R45 thru R62	Com'l	Resistor, 10K, ½W, 5% (Carbon)	20	
R44	Com'l	Resistor, 4.3K, ½W, 1% (Carbon)	1	
R63 thru R68	Com'l	Resistor, 15K, ½W, 5% (Carbon)	6	
R69 and R70	Com'l	Resistor, 68K, ½W, 1% (Carbon)	2	
R71 thru R76	Com'l	Resistor, 47K, ½W, 5% (Carbon)	6	

*NOTE: 1.2K is nominal value only. Value is factory selected for each instrument.

APPENDIX

SHIPPING INSTRUCTIONS

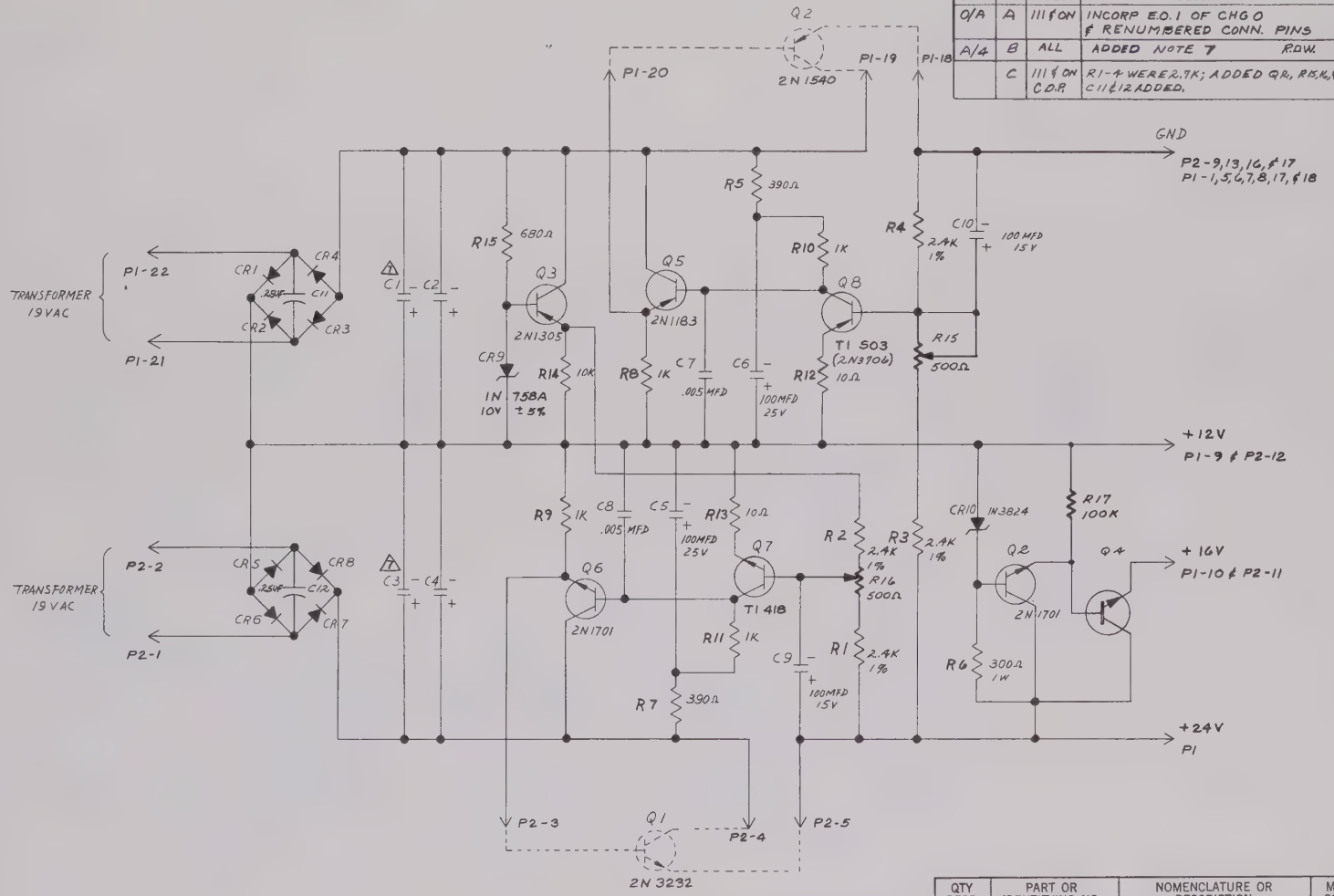
Depending upon location, the choice of carrier will vary. Never ship an instrument to us without having received shipping instructions. If requested, an estimate of charges can be made before work begins.

Be certain to pack the instrument carefully; while an outer and inner box, separated by two or three inches of excelsior is desirable, the instrument can be placed into a single container provided it is so packed that it will not shift about. As with the double box method, use two or three inches of shock-absorbent packing materials. The instrument itself should be first wrapped in heavy paper so as to keep excelsior or other particles from entering the instrument's louvres. If the original shipping container is in good condition, it may be used.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it does not operate or is damaged, a claim should be made with the carrier. The claim agent should receive a full report of damage, and this report sent to Non-Linear Systems, Inc. After receiving such a report we will advise you of the disposition of the instrument and arrange for its repair or replacement. Be certain to include model and serial number when corresponding.

REVISIONS					
ZONE	LTR.	EFFECT.	DESCRIPTION	DATE	APPROVED
C/A	A	III & ON	INCORP E.O.1 OF CHG O & RENUMBERED CONN. PINS	5-13-65 M.A.T.	R.T.W.
A/4	B	ALL	ADDED NOTE 7 R.D.W.	9-30-65	R.T.W.
	C	III & ON C.O.P.	R1-4 WERE 2.7K; ADDED QR, R15,16,17 C11&12 ADDED.	10-15-65 JAC	R.T.W.



QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.

PARTS LIST

⚠ C1 & C3 2000 MFD/50V MAY BE USED AS AN ALTERNATE FOR C1-C4.

6. Q8 - 2N3638 TRANSISTOR MAY BE USED IN LIEU OF T1503 PROVIDED A MIN BETA OF 60 IS MAINTAINED.
5. RESISTORS ARE ½ W. CARBON 5% TOL. UNLESS OTHERWISE SPECIFIED
4. R1 THRU R4 ARE PW1220 1% W.W.
3. Q1 AND Q2 ARE MOUNTED ON INNER CHASSIS
2. C1 THRU C4 ARE 1000 MFD/25V (SEE NOTE 7)
1. CR1 THRU CR8 ARE T14385 OR MOTOROLA IN4003

NOTES:

50-17	50-17	1	1
NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED	CONTR. NO.		
DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± .010 ANGLES ± 0° 30' FRACTIONS ± 1/32	DRAWN	L A M	12/2/64
	CHECK		2-2-65
	APPR		2-2-65
	RELEASE DATE	2-2-65	
MATERIAL			

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

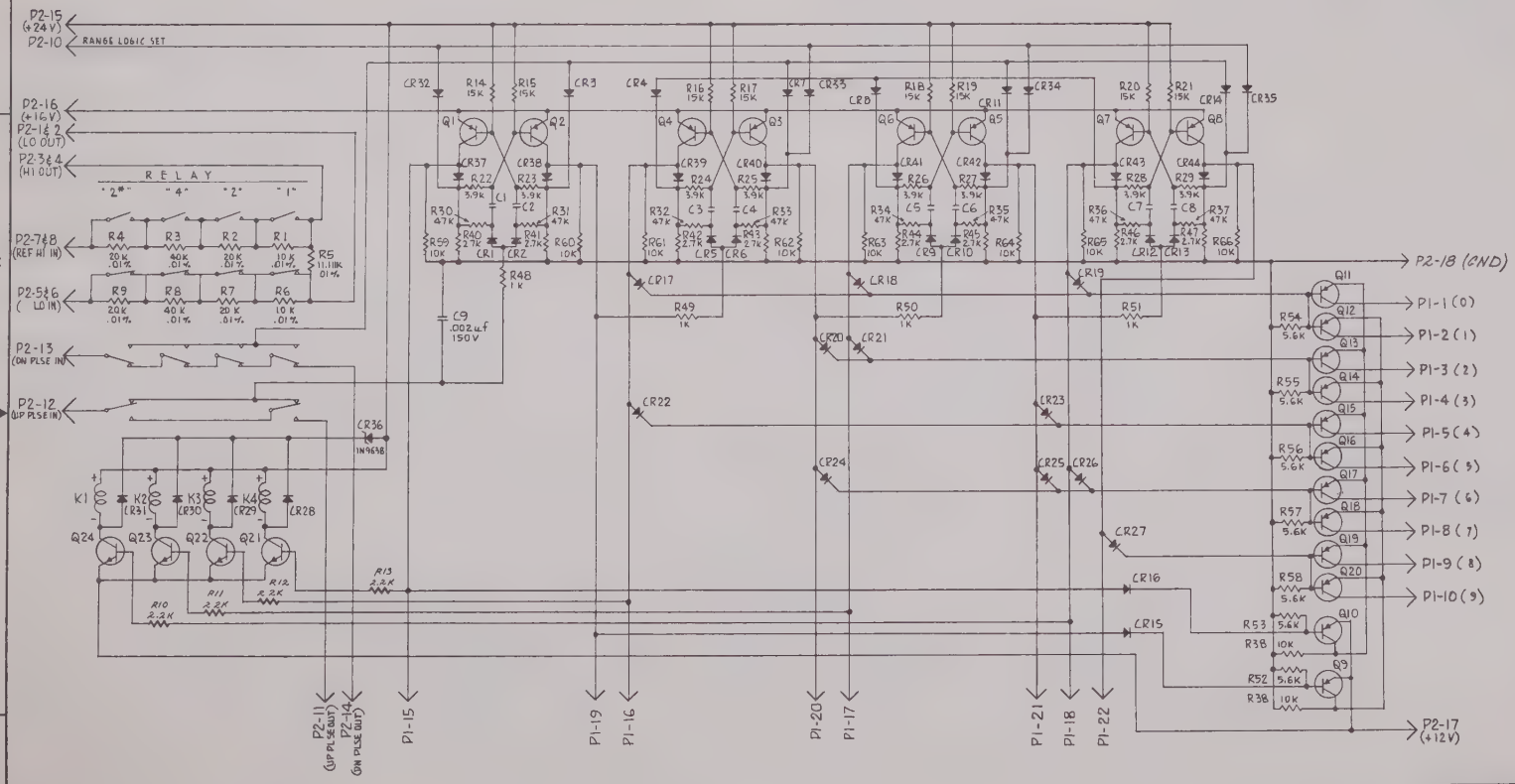
POWER SUPPLY ASSEMBLY

SERIES 5000

SIZE	CODE IDENT NO.	
C	03626	50-7
SCALE	WEIGHT	SHEET 2 OF 2

50-7 S/2

10/64 DIETERICH-POST CLEARPRINT 1000M-10



REVISIONS					
ZONE	LTR.	EFFECT.	DESCRIPTION	DATE	APPROVED
0/A	D	ALL	REDRAWN — ADDED R59 THRU R66 & CR37 THRU CR44	7-16-65 ARW	R.T.W
C/9	E	ALL	R5 CHG. FROM 11.11K TO 11.111K	8-18-65 MEA	E Murphy
B/8	F	ALL	CORRECTED SCHEMATIC ERROR	9-8-65 MEA	R. T. W.
C/12	G	ALL	P2-18(GND) ADDED	10-8-65 JAC	E Murphy

8 P2 MATES WITH J16 J20 J24 & J28
7. P1 MATES WITH J15, J19, J23 & J27
6. RESISTORS ARE ½W CARBON 5% TOL
5. DIODES ARE 5003-002
4. R1 THRU R9 ARE PW2016
3. Q21 THRU Q24 ARE 2N1304
2. Q1 THRU Q20 ARE 2N1305 (Q9-Q20 2N404A MAY SUBSTITUTE)
1. C1 THRU C8 ARE 0.01 MFD/150V

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.

PARTS LIST

50-17	50-17	4	4
50-28	50-28	3	3
NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
MATERIAL

CONTR. NO.
DRAWN L. KNAPIK 4-6-65
CHECK R. T. WARNER 4-20-65
APPR C. MEREDITH 4-20-65
RELEASE DATE 4-21-65

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC DECADE ASSEMBLY

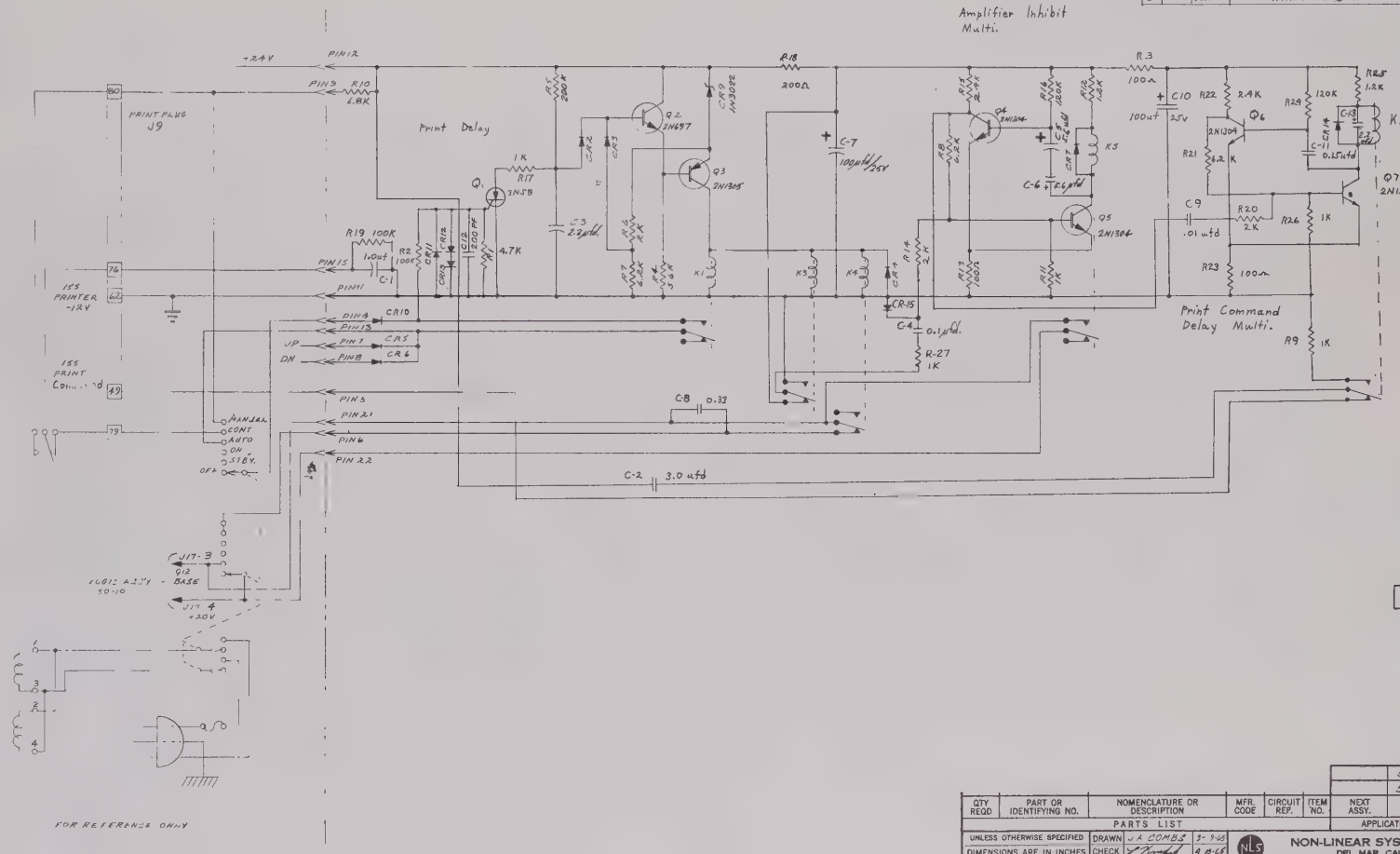
SERIES 5000

SIZE	CODE IDENT NO.	50-61
D	03626	
SCALE	WEIGHT	SHEET 2 OF 2

50-61 REV B

THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF NON-LINEAR SYSTEMS INC., AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT, NON-LINEAR SYSTEMS INC. RESERVES ALL PATENT, PROPRIETARY, DESIGN, USE, SALE, MANUFACTURING AND REPRODUCTION RIGHTS THEREIN.

REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED
A			Added Print Comm. Delay Multi. Revised Print Delay Circuit	5-5-65	R.T.W.
B		1094 ON	INCORP E.O. 1 OF CHG A #98	5-7-65	R.T.W.
C		ALL	INCORP E.O. 1&2 OF CHG. B #244	9-27-65	R.T.W.
D		ALL	R10-CHG. 11K TO 6.8K	9-31-65	R.T.W.



50-67
SHEET 2 D

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
						50-79	1	1	
						50-78	1	1	
		PARTS LIST				APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10
DO NOT SCALE THIS DRAWING
RELEASE DATE 4-15-65

DRAWN J.A COMBS 3-3-65
CHECK 4-10-65
APPR R.T. Warner 4-15-65
MATERIAL
FINISH

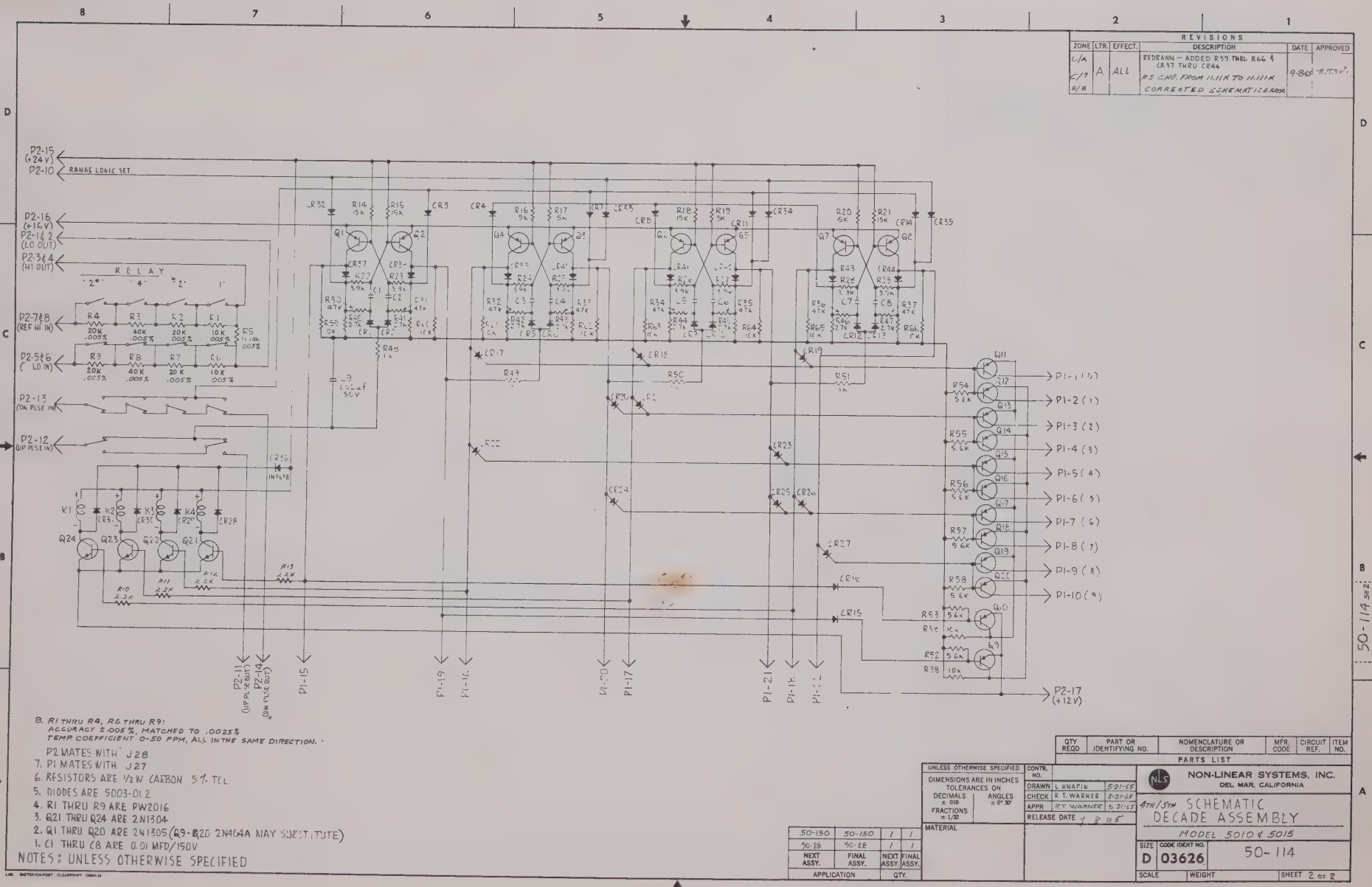
NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC DVL-1
"PRINT CONTROL" BOARD
5000 SERIES

CODE IDENT NO. 03626 | SIZE D | 50-67.
SCALE | WEIGHT | SHEET 2 OF 2

4. CR8 Omitted
3. ALL DIODES ARE NLS 5003-002
2. ALL RESISTORS ARE 1/8 W 5%
1. ALL RELAYS ARE NLS S-12-34
NOTES, UNLESS OTHERWISE SPECIFIED

DIETZGEN-POST CLEARPRINT 1559H-18



8. R1 THRU R4, R6 THRU R9: ACCURACY ±.005%, MATCHED TO .0025% TEMP COEFFICIENT 0-50 PPM, ALL IN THE SAME DIRECTION.
7. P1 MATES WITH J27
6. RESISTORS ARE ½W CARBON 5% TOL
5. DIODES ARE 5003-012
4. R1 THRU R9 ARE PW2016
3. Q21 THRU Q24 ARE 2N1304
2. Q1 THRU Q20 ARE 2N1305 (Q9-Q20 2N404A MAY SUBSTITUTE)
1. C1 THRU C8 ARE 0.01 MFD/150V

NOTES: UNLESS OTHERWISE SPECIFIED

P2 MATES WITH J28

REVISIONS					
ZONE	LTR.	EFFECT.	DESCRIPTION	DATE	APPROVED
C/A, C/7, B/8	A	ALL	REDRAWN — ADDED R59 THRU R66 & CR37 THRU CR44. P3 CHG. FROM 11.11K TO 11.111K. CORRECTED SCHEMATIC ERROR	9-8-65	A.T.W.

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.

PARTS LIST

50-150	50-150	/	/
50-26	50-28	/	/
NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
FRACTIONS ± 1/32
ANGLES ± 0° 30'
MATERIAL

CONTR. NO.
DRAWN L KNAPIK 5-21-65
CHECK R T. WARNER 5-21-65
APPR RT WARNER 5-21-65
RELEASE DATE 9 8 65

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

4TH/5TH SCHEMATIC
DECADE ASSEMBLY
MODEL 5010 & 5015

SIZE	CODE IDENT NO.	50-114
D	03626	
SCALE	WEIGHT	SHEET 2 OF 2

50-114 SH 2

THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF NON-LINEAR SYSTEMS INC. AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT, NON-LINEAR SYSTEMS INC. RESERVES ALL PATENT, PROPRIETARY, DESIGN, USE, SALE, MANUFACTURING AND REPRODUCTION RIGHTS THEREIN.

REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED
A		1	ADDED PRINT CONTROL WIRING		
B		ALL	ADDED RATIO WIRING & FILTER SWITCH	6-14-65 JAE	

INSERT POLARIZING TAB BETWEEN PINS #5 IN J28 & J32

J32 J28 J24 J20 J16 J14 J12

J31 DECADE 5
J27 DECADE 4
J23 DECADE 3
J21 PRINT CONT.
J19 DECADE 2
J17 LOGIC
J15 DECADE 1

(TYP) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

TO READ OUT (TYP.)

SPECTRA-STRIP ROUTE TO READ OUT

REMOVE CONNECTOR PINS A3 SHOWN (J13 & J11)

J13 AMP, RANGE, & POL.

J11 POWER SUPPLY

CHASSIS GROUND

F1

R2 100K 1% C.F. (50-74)

58V A.C. C.T.

21VAC

21VAC

T1

Q1 (50-73) 2N3232 (MOUNTED ON CHASSIS)

Q2 (50-73) 2N1540 (MOUNTED ON CHASSIS)

FILTER SW (S-5)

PATIO (S-4)

"OFF" "ON" RATIO "RATIO"

J3 (REAR) A B C D E

PLUS MINUS COMMON GUARD SHIELD CHASSIS GND

S2 (POWER)

S1 (FUNCTION) (1 WAFER)

A WIPER A1 A2 A3 A4 A5 A6

B WIPER B1 B2 B3 B4 B5 B6

"STANDBY" OFF ON

R1 (50-93) CW

SENSITIVITY POT.

SIGNAL HI
SIGNAL LO
GUARD BOX
CHASSIS GND

J2 (REAR) A B C D

DECADE PD D5 D4 D3 D2 D1

+ − V R

50-154 B

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY	FINAL ASSY.
		PARTS LIST				50-151	50-150		
						APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± .010 ANGLES ± 0° 30' FRACTIONS ± 1/32

SURFACE ROUGHNESS PER MIL-STD-10

DO NOT SCALE THIS DRAWING

RELEASE DATE

DRAWN 6-14-65
CHECK 6-14-65
APPR 6-14-65
MATERIAL
FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

"SCHEMATIC"
MAIN BOARD
SERIES 5000 MODEL 5015

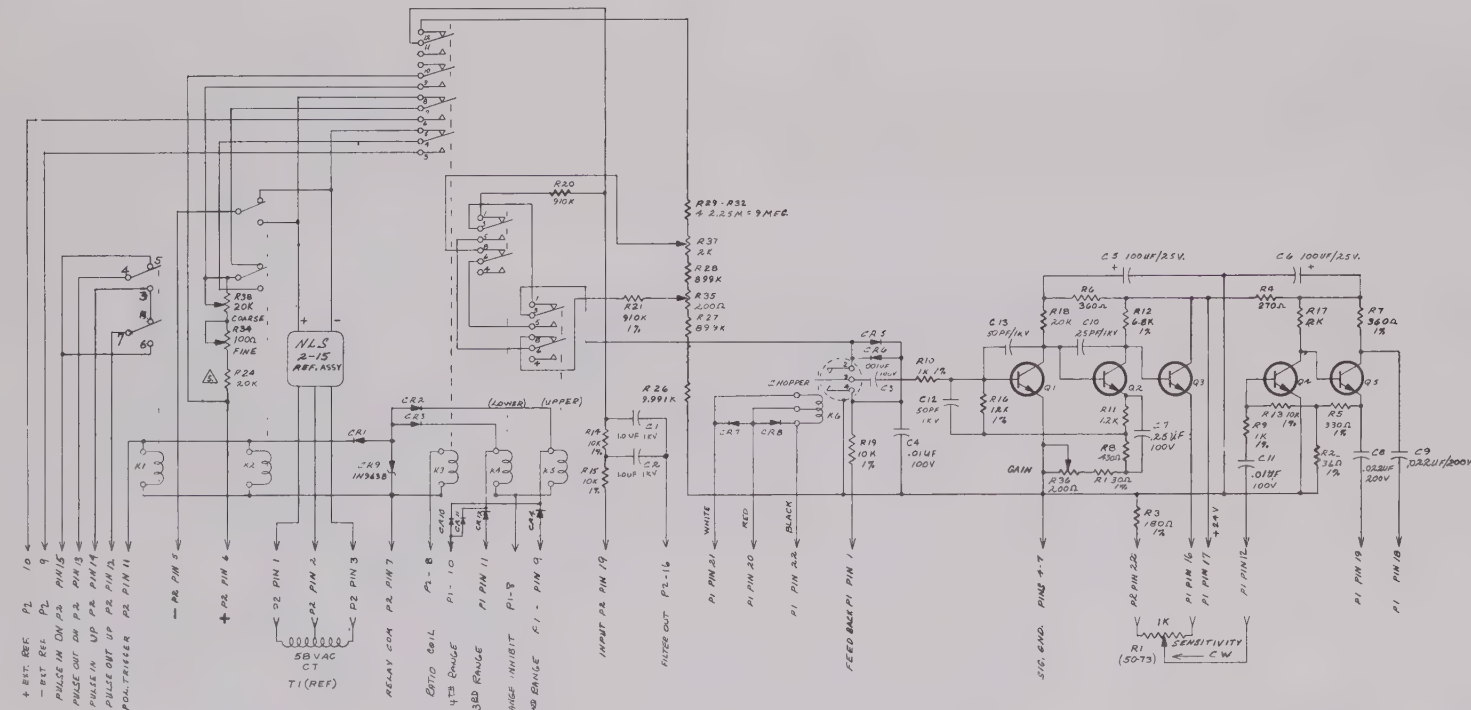
CODE IDENT NO. 03626 | SIZE D | 50-154

SCALE | WEIGHT | SHEET 2 OF 2

KEUFFEL & ESSER CO. DIETZGEN POST CLEARPRINT 1000H 10

THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF NON-LINEAR SYSTEMS INC., AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT, NON-LINEAR SYSTEMS INC. RESERVES ALL PATENT, PROPRIETARY, DESIGN, USE, SALE, MANUFACTURING AND REPRODUCTION RIGHTS THERETO.

REVISIONS					
SYM	ZONE	EFFECT.	DESCRIPTION	DATE	APPROVED
A		ALL	P14 TO WAS 15 P15 WAS 14	8-21-65	
B		ALL	2-15 REFERENCE ASSY WAS 2-11	9-24-65	
C		ALL	NOTE 2 WAS CR-1-CR-8 ADDED	DEC 65	
D		ALL	INCORP E.O.1 OF CHG 'C'	10-1966	
E		ALL	REVERSED P2-14 & -15; P2-18 CHGD FROM K1-B TO K1-3	11-1966	



50-177 S/S D

△2 SELECT TO MATCH 2-15 REFERENCE

NOTES-
1. RESISTORS R1-R22 ARE 1/2 W 1% GENERAL PURPOSE; R23-R25 PW 1220; R26-R32 PW 2016.
2. DIODES CR1-CR8 & 10-11 ARE 5003-002 (UG315)
3. ALL TRANSISTORS ARE TI 418 Q1-Q5.
4. ALL RELAYS ARE PRINTACT 12BW3G K1-K5.

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.	NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
		PARTS LIST				APPLICATION		QTY.	
						50-193	50-193	1	1
						50-150	50-150	1	1

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010 ANGLES ± 0° 30'
FRACTIONS ± 1/32
SURFACE ROUGHNESS PER MIL-STD-10 ✓
DO NOT SCALE THIS DRAWING
RELEASE DATE 8-25-65

DRAWN J.A. COMBS 8-21-65
CHECK [illegible] 8-25-65
APPR T.J. Warner 8-25-65
MATERIAL
FINISH

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC

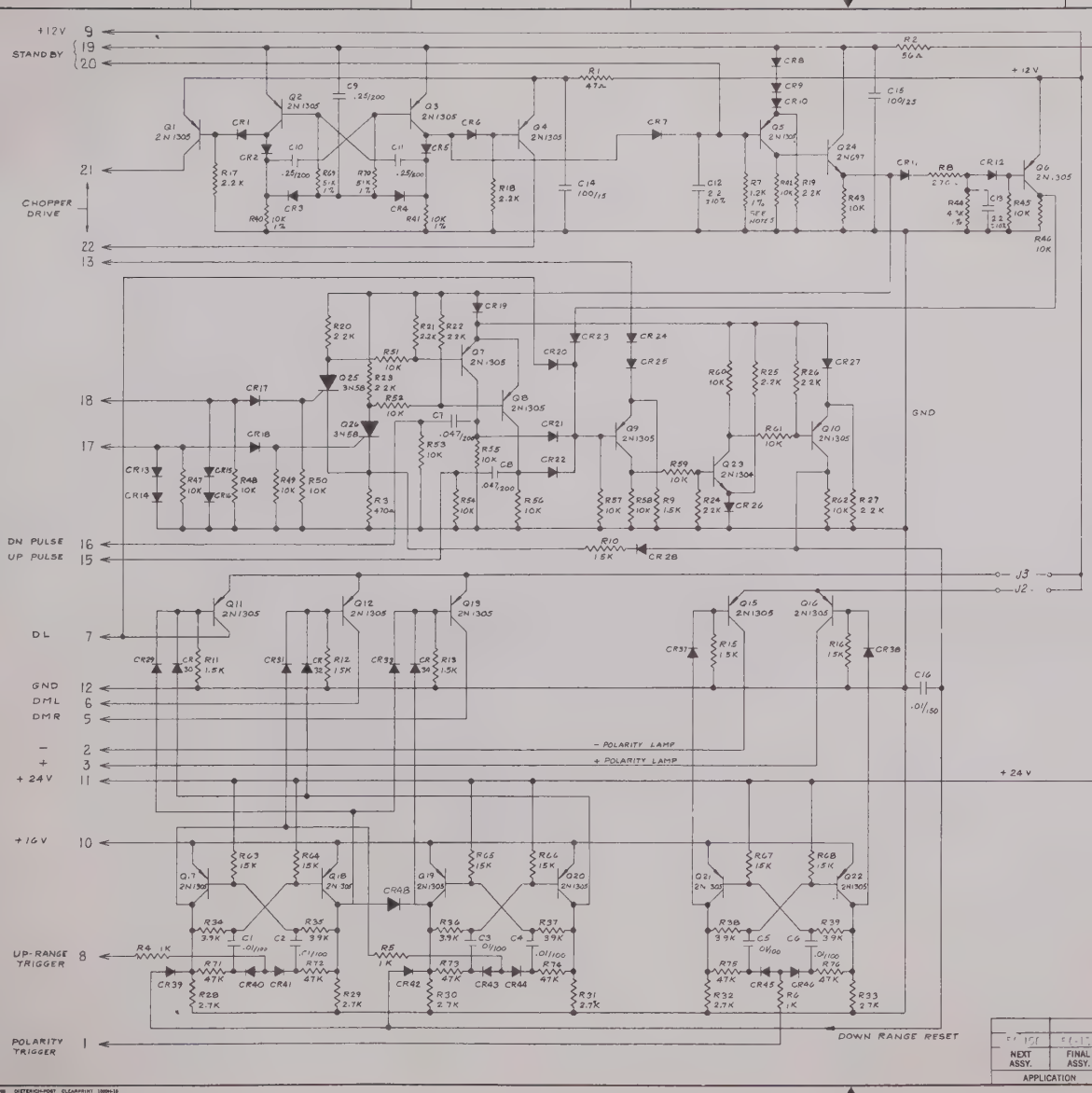
AMPLIFIER, RANGE, & POLARITY

MODEL 5013 & 5020

CODE IDENT NO. 03626 | SIZE D | 50-177

SCALE | WEIGHT | SHEET 2

DIETZGEN PORT CLEARPRINT 1000H-30



REVISIONS					
ZONE	LTR	EFFECT	DESCRIPTION	DATE	APPROVED

5 RESISTOR R7 TO BE SELECTED DURING FINAL CHECK & CALIBRATION. NOMINAL VALUE IS 1.2K. USE DECADE RESISTANCE BOX TO SELECT PROPER VALUE PER NLS DOC. #637.

4 TRANSISTOR 2N404A MAY SUBSTITUTE FOR 2N1305 Q11 THRU Q16

3. CAPACITANCE VALUES ARE STATED IN MICROFARADS

2. RESISTORS ARE ½W 5%

1 DIODES ARE 5003-002

NOTES: UNLESS OTHERWISE SPECIFIED—

QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.
PARTS LIST					

NEXT ASSY.	FINAL ASSY.	NEXT ASSY	FINAL ASSY.
APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED	CONTR. NO
DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS ± .010 FRACTIONS ± 1/32 ANGLES ± 0° 30'	DRAWN A.R WALLIN 7-28-65
	CHECK
	APPR
	RELEASE DATE 8-2-65
MATERIAL —	—

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC—
LOGIC ASSEMBLY
MODEL 5015

SIZE	CODE IDENT NO.	
D	03626	50-192
SCALE	WEIGHT	SHEET 2 OF 2

50-192 SH 2

REVISIONS					
ZONE	LTR.	EFFECT.	DESCRIPTION	DATE	APPROVED
	A	ALL	ADDED S4-A1 & S4-A2 CONN. J9-1 WAS CONN. TO. J17-14 J9-5 WAS CONN. TO. J17-16 J9-2 WAS CONN. TO. J17-17 J9-7 WAS CONN. TO. J17-18 J9-18 WAS CONN. TO. J17-20 J9-25 WAS CONN. TO. J17-21	9-23-65 R.C.W.	

J9

3	
11	J15-1 "0"
17	J15-2 "1"
24	J15-3 "2"
30	J15-4 "3"
36	J15-5 "4"
42	J15-6 "5"
48	J15-7 "6"
54	J15-8 "7"
60	J15-9 "8"
67	J15-10 "9"
75	S4-A1 (TYP)
82	

DECADE 1

J9

7	J17-5
14	J19-1
21	J19-2
27	J19-3
33	J19-4
39	J19-5
45	J19-6
51	J19-7
57	J19-8
64	J19-9
72	J19-10
78	S4-A2

2

J9

2	J17-6
10	J23-1
16	J23-2
23	J23-3
29	J23-4
35	J23-5
41	J23-6
47	J23-7
53	J23-8
59	J23-9
66	J23-10
74	
80	J21-9

3

J9

5	J17-7
13	J27-1
20	J27-2
26	J27-3
32	J27-4
38	J27-5
44	J27-6
50	J27-7
56	J27-8
63	J27-9
71	J27-10
77	

4

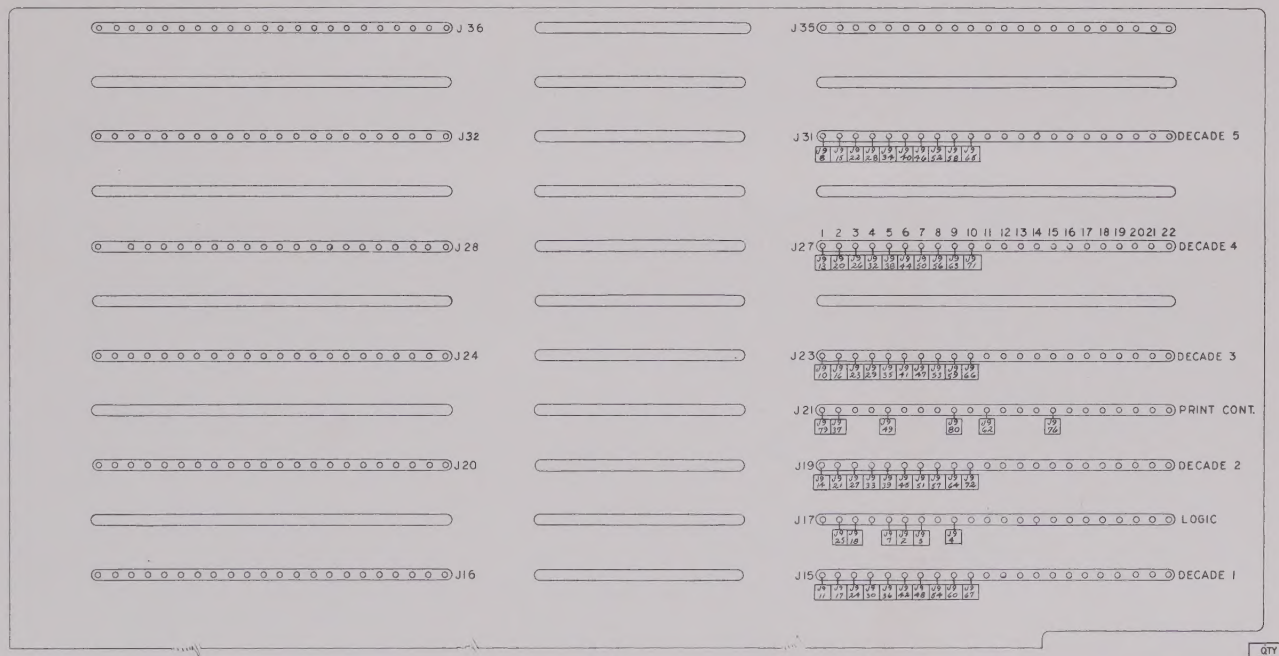
J9

1	
8	J31-1
15	J31-2
22	J31-3
28	J31-4
34	J31-5
40	J31-6
46	J31-7
52	J31-8
58	J31-9
65	J31-10
73	
79	J21-1

5

J9 (201396-1 CONN. MALE GUIDE AT PIN 2)

4	J17-9 +12V
12	
18	J17-3 "+"
25	J17-2 "−"
31	
37	J21-2
43	
49	J21-5
55	
62	J21-11
70	
76	J21-15



QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MFR. CODE	CIRCUIT REF.	ITEM NO.

PARTS LIST

NEXT ASSY.	FINAL ASSY.	NEXT ASSY.	FINAL ASSY.
APPLICATION		QTY.	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS ± .010
ANGLES ± 0° 30'
FRACTIONS ± 1/32

CONTR. NO.
DRAWN J.A. COMBS 8/2/65
CHECK W. Trumbull 8-25-65
APPR. W. T. Wilson 8/27/65
RELEASE DATE 8-11-65

MATERIAL

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIFORNIA

SCHEMATIC DVL-1
ADDITION FOR 5 DIGIT PRINT-OUT
MODEL 5015 & 5020

SIZE	CODE IDENT NO.	50-202
D	03626	
SCALE	WEIGHT	SHEET 2 OF 3

50-202 SH 2

1-48 DIETZGEN-POST CLEARPRINT 1000H-50

Warranty

Non-Linear Systems, Inc., warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. This warranty is effective for One Year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. This warranty does not cover lamp bulbs, semiconductors, tubes, choppers, fuses or batteries. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started. For items such as sub-assemblies, assemblies or instruments not of our manufacture, the manufacturer's warranty, if any, shall apply.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.
2. On receipt of shipping instructions, forward the instrument, prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the warranty.

NOTE: In the case of instruments shipped collect, repairs cannot proceed until payment (or purchase order number) is received for shipping charges.

FORM W865

MOVE ORDER

HONEYWELL INC.

ORDER NO. AND CHANGE NO: MUST BE SHOWN ON ALL PACKAGES, CASES, SHIPPING MEMOS, BILLS OF LADING, EXPRESS RECEIPTS, INVOICES AND CORRESPONDENCE TO RECEIVE PROPER PAYMENT.

IDENTIFY DOCUME ENCLOSE

ORDER NO.	CHANGE NO.	BUYER	DATE OF ORDER	VENDOR NO.
PSY545518	00	44	9/12/66	271600

CONTRACT NO.

PRIORITY RATING

F.O.B. POINT AND FREIGHT ALLOWANCE: DEL MAR, CALIF.

SHIPPING

ANY EXCESS TRANSPORTATI TIONS WILL BE CHARGED BA ONE DAY TO THE SAME ADD ANY VALUE. DO NOT INSUR

PARCEL POST: UP TO

EXPRESS: IF OVI

FREIGHT:

SPECIAL:

VENDOR

NON LINEAR SYSTEMS
C/O TORKELSON ASSOCIATES
4820 WEST 77TH STREET
MINNEAPOLIS, MINNESOTA

SHIP MATERIAL AND MAIL ORIGINAL BILL OF LADING TO
COMO AVE AT EUSTIS MPLS MINN

MAIL INVOICE TO
AERO DIV 260

ITEM	QUANTITY	UNIT	RR	PART OR SPEC. NO. AND DESCRIPTION
0	1	EA.		MODEL 5015 N. L. S. RATIOMETER
				CONFIRMING
				DELIVER: SEPTEMBER 26, 1966

INCORPORATED INTO THIS PURCHASE ORDER BY REFERENCE AND MADE A PART HEREOF.

R. E. MOHR

TO WHOM ALL CORRESPONDENCE BUYER, SHOULD BE REFERRED AT INVOICING ADDRESS SHOWN ABOVE.

THIS PURCHA AND CONDI GENERAL TER APRIL 1966.

MPG 4005

PROCUREMENT
HONEYWELL

RECEIVING COPY

non linear
systems, inc.

DEL MAR, CALIFORNIA

www.manualsplus.com
1022474